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INVESTIGATION OF GAMMA RADIATION HAZARDS INCIDENT TO AN UNDERWATER ATOMIC EXPLOSION

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SECTION I. SUMMARY

1. In order to properly account for the attack by means of atomic weapons in the design of new construction, fundamental data on the hazards of gamma radiation (penetrating radiation) resulting from an underwater atomic explosion was required. Inquiries indicated that the existing data, based on Operation Crossroads, was inadequate for design purposes. Consequently, the Bureau of Ships undertook on 3 November 1947 to investigate the basic information collected during Test Baker in order to obtain adequate design data for considering measures to protect against gamma radiation. Detailed history and results of this investigation are contained in Section II of this report. Section I is a summary of the results of the investigation.

2. Since previous reports from Operation Crossroads indicated that the base surge which formed at the base of the Test Baker water column and moved outward, enveloping the target array, contained nearly all of the gamma radiation hazard, the extent and rate of growth of the base surge was the subject of the initial investigation. The growth and extent of the base surge was charted by analysis of photography of the Test Baker detonation as described in Section II, paragraphs 3 to 8. Figures 3 and 5 completely describe the motion of the base surge from detonation to detonation plus seven minutes. Figure 4 depicts the time distance curves of the movement of the base surge in the upwind, crosswind and downwind directions. The base surge forms about ten seconds after detonation around the base of the collapsing water column and moves outward in a

uniform fashion to about the 1000 yard circle. The mean velocity of the advance during this period is about 50 knots. Beyond the 1000 yard circle, the velocity of the base surge in the upwind direction begins to diminish rapidly, being but 15 knots at the end of the first minute. Motion in the upwind direction ceases at about two minutes after detonation. The maximum distance reached is about 1800 yards. Stagnation of the upwind side of the base surge corresponds to a rapid deceleration of the crosswind and downwind sides. The maximum crosswind extent (2700 yards) is reached at about detonation plus three minutes. At the same time, the velocity of the base surge in the downwind direction reaches a constant velocity approximating that of the wind (six knots). Thereafter, movement of the base surge is controlled entirely by the wind. Beyond 3000 yards downwind, the base surge loses its opaque cloudlike appearance. It lifts from the water and begins to disintegrate under the action of the wind. Vessels situated at about 3500 yards downwind never quite disappear from view.

3. The total dose of gamma radiation received by each target ship exposed during Test Baker was recorded as the darkening of photographic films placed in various locations throughout the vessels. The total dose thus recorded was received in two ways:

(a) Direct gamma radiation from radioactive particles in suspension in the base surge. This "surge radiation" operates on the particular film badge from the time the surge approaches close enough for the gamma radiation to penetrate to the badge until the base surge retires downwind or lifts above the array, depending upon the location of the target containing the badge.

(b) Gamma radiation emanating from fission products deposited on the weather surfaces of the vessel. This "deposit radiation" operates on the film badge from the time the fission products begin to be deposited in the vicinity of the target until the badge is removed from the area.

4. The dose from the surge and the dose from the deposit combine to form the total dose recorded on the film badge. The total dose as recorded by the darkening of the film cannot be broken up into the two constituent doses. The deposit dose, however, can be obtained independently of the film badge data by measuring the intensity of gamma radiation on the weather surface at some time after contamination by means of a Geiger Counter or similar device. The deposit dose is obtained by integrating, between proper limits, the area under a decay curve passed through the measured value, as shown in Figure 11 and explained in Section II, paragraph 27 and 28. Once the deposit dose is obtained in this manner, the surge dose can be inferred by subtracting the deposit dose from the total dose as recorded by the film badge.

5. After an exhaustive survey of prior reports (Section II, paragraphs 11 through 25), available in the file of the Armed Forces Special Weapons Project, it was considered desirable to return to the basic data in order to arrive at usable criteria for design purposes. In the process of obtaining accurate quantatative analyses of the distribution of gamma radiation dosages throughout the array, considerable new light was thrown upon the mechanisms by which the gamma radiation hazard is propagated during an underwater explosion. It was discovered that, contrary to previous thought, the base surge was not the primary contaminating

mechanism of the underwater explosion. Consideration of the distribution of the deposit dose, as analyzed from Geiger Counter records, led to the hypothesis that the primary deposit occurred as the result of early radioactive fallout or "rain" from the mushroom head. This hypothesis was substantiated in numerous ways throughout the study. The early fallout from the mushroom head (Figures 16 through 19) tended to form a "ring" of high deposit doses around the center of burst, each maximum corresponding to a prominent fallout visible in photographs. An expanded section of this "fallout ring" is shown in Figure 20. The mean level of deposit dose in way of the fallout ring is about 4000 roentgens. Of this amount, about 3500 roentgens is attributed to the fallout from the mushroom head and about 500 roentgens to the deposit resulting from condensation of the base surge. The distribution of deposit over the Test Baker array is shown in Figure 15 by contours of deposit dose in equivalent roentgens.

6. The total unshielded dose of gamma radiations experienced by the target vessels was determined by a comparative analysis of film badge data (Section II, paragraphs 42 through 51). Figure 28 shows the distribution of total gamma radiation dose over the Test Baker array by means of contours of total dose in equivalent roentgens. Contours of surge dose were obtained by subtracting the deposit doses represented in Figure 15 from the total doses represented in Figure 28. These contours are plotted in Figure 29.

7. Figures 3, 5, 15, 28 and 29 and the accompanying text in Section II adequately describe the propagation and distribution of the gamma radiation hazard which occurred in Test Baker. For design purposes, a more generalized statement of the hazards involved is necessary. A major

factor controlling the distribution of the gamma radiation hazard during Test Baker was the wind velocity. The wind velocity at the time of the Test Baker burst was six knots. This is not representative of the mean wind velocity to be expected. After some study, a design wind velocity of 15 knots was assumed. Figure 6 illustrates the growth and movement of the base surge under a wind velocity of 15 knots. The development is shown to detonation plus five minutes or 4000 yards on the downwind side. Further development is not investigated due to the lifting and disintegration of the surge at this time. Paragraphs 54 through 60 of Section II describe the changes in gamma radiation distribution resulting from the assumption of a design wind speed of 15 knots. Figure 30 represents the mean or average distribution of deposit dose under these conditions. Note that an "ideal" ring maximum of 4000 roentgens is assumed in lieu of the various maxima exhibited by the deposit dose distribution in Test Baker (Figure 15). Figure 31 represents the mean or average surge radiation dose distribution under design conditions. Since surge radiation is great only in the early moments of an underwater burst, an increase in wind velocity has very little influence upon the surge radiation dose distribution. Figure 32 represents the total gamma radiation dose which may be expected under mean conditions with a wind velocity of 15 knots. It was obtained by summation of the two constituent doses represented by Figures 30 and 31. The shape of the contours inside the 6000 roentgen contour is of little practical value although interesting from a theoretical point of view as discussed in Section II, paragraph 59. For design purposes, an even growth to a 9000 roentgen maximum at the center of burst can be assumed.

8. Section II contains the detailed analysis and results. Since the evaluation of prior work on this problem was made very difficult by a lack of statements as to assumptions and formulae used in obtaining results, a full history of assumptions used, processes and formulae developed and accuracies obtained is contained in Section II along with discussions of physical interpretation of the data in many instances. The magnitude of this phase of the problem of protecting naval vessels against penetrating radiations is such as to preclude additional study into the time-intensity and other characteristics of the gamma radiation hazard at this time. These characteristics will be the subject of future studies.

9. Basic data on film badge exposure and deposit dose calculations which were obtained from the files of the Armed Forces Special Weapons Project are referred to in Section II as Documents A and B. These titles were applied by the Bureau to the data which was in rough form without formal titles or identification.

10. Illustrations for this report have been classified on an individual basis in order to facilitate their use in design or training apart from this report. The complete report, text and illustrations, is classified Top Secret.

SECTION II. Detailed Analysis

1. Incident to the design of the anti-submarine warfare vessel, several questions arose concerning the amount, character and duration of the radiological contamination experienced as the result of an underwater atomic detonation and at what ranges from the burst this contamination would affect a naval vessel. As a result, the Atomic Warfare Defense Section, Bureau of Ships, initiated a study of the problem on 3 November 1947. The immediate object of the study was to determine the gamma radiation hazard from a Test Baker type detonation against the CLK Class vessel. The long-range objective was to be an assessment of the gamma radiation hazard against all major types and classes of naval vessels.

2. Consultation with the Technical Directors group, Crossroads Division, Armed Forces Special Weapons Project revealed that the radiation hazard emanated almost entirely from the base surge which formed at the base of the water column about ten seconds after detonation and moved outward, enveloping the target array. The base surge was composed of a very heavy mist or fog containing radioactive materials and fission products. As the base surge moved outward condensation occurred and a portion of the radioactive materials "rained out" on the target vessels, contaminating the topsides. The Technical Director, Dr. Scoville, estimated that about 50% of the total radiation dose registered by each target vessel was the result of radioactive decay of the material deposited on the target vessel. The other 50% of the total dose was radiated from the mist during the time in which the vessel was enveloped by the mist. In order to assess the hazard to the vessel while underway, data as to the rate of growth of the base surge and the radiation gradient at various stages

of growth is necessary. A survey of available data indicated the existence of much conflicting or unsatisfactory data and considerable missing information. It was decided to investigate the growth of the base surge independently by means of analysis of photography of the Test Baker detonation so as to form a firm foundation for the remainder of the study. The principal films used were AF Nos. 592, 593, 647, 632, 598, 629 and 637. The results of this analysis are shown in Figure 1. The estimated time of contact of the base surge with the nearest point of the target vessel is recorded for each film on which the particular vessel is observed. Where the camera angle permitted, the time of actual contact was observed. If contact occurred between successive frames or if the camera angle did not permit an observation of the near point of the vessel, the progress of the surge over the vessel was observed and an estimate of surge velocity made. With this information, the time of contact was readily determined. At the right margin of Figure 1, is the average or consensus of all observations on each target vessel. These values of time are plotted in Figure 2 at the appropriate locations of the nearest points of the targets. The position of the targets has been oriented on the basis of the announced wind bearing of 135° true. Contours of time up to three minutes have been added. The shape of these contours indicate that the actual direction of wind during and immediately after detonation was more in the nature of 150° true. Figure 2 also indicates the somewhat uneven growth of the surge. Photographs show a definite scalloped effect on the periphery, with minor protrubances and identations occurring from time to time.

4. For design purposes, a faired curve is desirable which represents a mean progress of the base surge. Faired curves of the development of the base surge up to three minutes are shown in Figure 3. Not only have the minor irregularities of Figure 2 been faired but maximum values are re-oriented to the downwind direction (150° true) and the curves are now symmetrical about the wind axis as would be expected. Certain characteristics of the growth of the base surge are visible in Figure 3. The base surge begins to form around the base of the water column at about detonation plus ten seconds. The base surge is circular in plan, the radius at formation being about 350 yards. At 15 seconds, the surge is still circular and has reached the 500 yard circle. The surge remains circular until it reaches the 900 yard circle at 30 seconds after detonation. Thereafter, it begins to distort from the original circular plan. On the upwind side, the growth of the base surge is inhibited by the adverse effect of the wind and approaches a flat elliptical shape, the crosswind dimensions of the base surge being the transverse axis. The rate of growth of the base surge downwind is aided by the wind and assumes an elliptical shape in which the crosswind dimension is the conjugate axis. The extreme limit of the base surge upwind is 1800 yards. Downwind, it extends to about 3000 yards by the end of three minutes. The characteristic egg-shaped plan of the base surge is clearly visible in several aerial photographs. The maximum crosswind extent of the base surge is about 2700 yards from the center of detonation. Presumably, this distance is that at which the base surge exhausts the energy supplied to it by the detonation and, were no wind existing, the surge would come to rest in a circular shape with the edge of the surge on the 2700 yard circle.

5. By passing a section through the origin of Figure 3, the time distance curve of the motion of the base surge up to three minutes can be determined for any desired direction. Figure 4 depicts the time-distance curves of the movement of the base surge in the upwind, crosswind and downwind directions. The character of these curves is interesting. The base surge forms roughly ten seconds after detonation around the base of the water column (about 350 yards from the center of detonation). The base surge advances outward in a uniform fashion to about the 1000 yard circle. The mean velocity of the base surge during this period is about 50 knots. During this period of nearly constant velocity, energy is being continuously added to the surge by the disintegration of the water column. Beyond the 1000 yard circle, the velocity of the base surge in the upwind direction begins to diminish rapidly. At the end of the first minute the velocity upwind is but 15 knots. The crosswind and downwind velocities are nearly equal. At one minute the base surge has advanced about 100 yards further in the downwind direction than in the crosswind direction.

6. Motion in the upwind direction ceases at about two minutes after detonation. The maximum distance reached is about 1800 yards. Stagnation of the upwind side of the base surge corresponds to a rapid deceleration of the crosswind and downwind portions. The maximum crosswind extent of the base surge (2700 yards) is reached at about three minutes. At the same time, the velocity of the base surge in the downwind direction reaches a constant velocity approximating that of the wind. These two facts support the conclusion that the energy originally present in the base surge is exhausted at the end of three minutes. Thereafter,

movement of the base surge is controlled entirely by the wind. Beyond 3000 yards downwind, the base surge loses its opaque cloudlike appearance. It lifts from the surface of the water and begins to disintegrate under the action of the wind. Vessels situated at about 3500 yards downwind never quite disappear from view. Consequently determination of the behavior and velocity of the base surge is difficult.

7. Beyond detonation plus three minutes, the base surge is moving only in the downwind sense. One observation was made in this direction, that on the CONYNGHAM. The estimated time of contact was six minutes. This point is plotted in Figure 4 as a circle and agrees well with a straight line drawn from the downwind curve at three minutes with an arbitrary slope equivalent to a velocity of six knots (the probable wind velocity). On the upwind side, the base surge begins to retreat after detonation plus three minutes. Three observations of the retreating surge were obtained and are plotted on Figure 4 as triangles. These observations agree very well with a straight line of arbitrary slope equal to six knots velocity drawn from the upwind curve at three minutes. The motion of the base surge is thus completely represented out to eight minutes after detonation. Study of Figure 4 indicates that the base surge reaches a maximum diameter in the upwind-downwind direction of about 4800 yards at detonation plus three minutes. The base surge reaches a crosswind maximum diameter of about 5400 yards at the same time. Thereafter, the base surge dimensions are static and the surge moves bodily downwind at wind velocity. The maximum crosswind diameter is about 600 yards greater than that in the upwind-downwind direction, indicating that the wind was more effective in limiting upwind growth than it was

in promoting the downwind extent of the surge. This appears to be reasonable.

8. Figure 5 describes the bodily movement of the base surge downwind from detonation plus three minutes to detonation plus seven minutes. Figures 3 and 5 together completely describe the motion of the base surge from detonation to detonation plus seven minutes. As stated before, beyond seven minutes the motion of the base surge is difficult to determine. It has lifted to form a cloud at about 1000 ft. above the surface and has begun to disintegrate. However, for vessels underway, the motion of the base surge at this time is largely of academic interest, as the vessels would have already cleared the area. For this reason, inquiry into the motion of the base surge beyond detonation plus seven minutes is not made.

9. For purposes of assessing the radiation hazard from an underwater explosion upon vessels underway, the data represented by Figures 3 and 5 is not entirely satisfactory as the wind velocity (six knots) which was present during Test Baker is not representative of the mean wind velocity to be expected. On the basis of study of available data concerning the mean wind velocity in probable operating areas, a wind velocity of 15 knots was chosen for design purposes. In Figure 4 two dashed lines with slopes corresponding to a velocity of 15 knots have been added tangent to the downwind and upwind curves. Under this assumption, the base surge ceases expanding and begins to move downwind at 15 knots at about detonation plus 2 1/2 minutes. The crosswind curve is unaffected. Although it appears obvious that the shape of the curves prior to 2 1/2 minutes would be altered somewhat by the increased wind velocity, any adjustment would be highly arbitrary. Consequently, no adjustment is made.

10. Figure 6 represents the development of the base surge of a Baker-type atomic bomb under the influence of a 15 knot wind as indicated. The development is shown to detonation plus five minutes or 4000 yards on the downwind side. Further development is not investigated due to lifting and disintegration of the surge as explained in paragraph eight. The increased wind velocity probably would cause lifting and disintegration of the base surge at some range closer than that experienced in Test Baker but an effective surge is assumed to 4000 yards. It is expected that few, if any, cases of vessels underway will involve contact with the base surge in the neighborhood of detonation plus five minutes in any event.

11. Basic data on the radiation intensities encountered during Test Baker are derived from film badges placed in various locations on the target vessels. The placing of the film badges on the ships was accomplished by the ship's crew in accordance with instructions which indicated the compartment number and frame number for the location of each badge. Further details of the placing of the badges were left to the judgment of the ship's force. As a result, no information as to the height above deck, orientation of badge, or relationship to location of heavy equipment is known. Study of the available data indicates that such variables resulted in wide variation of doses received by badges subjected to approximately the same radiation.

12. The data derived from film badges consist of measures of total radiation dose in roentgens received by the film-badges. The process by which the density of fogging of the film is converted into radiation dose is subject to error especially for very light doses and very heavy doses. In general, the reading obtained may be in error by as much as a factor of 2.

13. Document A, made available by the Armed Forces Special Weapons Project for use in this study, contains detailed information on film badge dosages from Test Baker. The basic data from Document A is reproduced as Figure 21. It is purported to be the best available information. The great majority of film badges were placed within the ship structure and thus record the dosage as influenced by the shielding effect of structure and equipment. There were 16 film badges located in topside, presumably unshielded, locations on 13 ships. Since these badges would apparently offer the most accurate data on unshielded dose at the respective target vessels, it is interesting to note their performance. Three vessels, PENSACOLA, SALT LAKE CITY and BRISCOE had two topside film badges. On PENSACOLA, badge 3524, located on the port side of No. 1 mount, and therefore nearest the burst, registered 6700 roentgens. Badge 3544, located on the outside of No. 4 mount registered 10,000 roentgens. The variation was 3300 roentgens or roughly 50% of the smaller value. On SALT LAKE CITY, badge 3518, located under No. 4 mount and hence closest to the burst recorded 1600 roentgens. Badge 3514, under a forward mount, recorded 2400 roentgens. The variation, 800 roentgens, was 50% of the smaller reading. BRISCOE was nearly broadside to the burst. The burst was on the port beam. Badge 3745, located on a port side 20 mm. AA gun, registered 6200 roentgens. Badge 3755, on the starboard 20 mm. mount opposite, registered 8000 roentgens. A variation of 1800 or about 30% of the smaller value is apparent. It is obvious from the above that radiation intensities recorded by unshielded film badges are very uncertain. High readings may result from conditions which allow a concentration of fission products to accumulate in the immediate area of the badge. Low readings most probably result from shielding provided by topside equipment and structure.

14. The readings on the unshielded badges when compared with the dosage registered on badges below deck on the same vessel also provides considerable information as to the reliability of the badge readings:

Ship	Unshielded Badge	Highest Shielded Reading
WAINWRIGHT (DD419)	166 R	340 R
PENSACOLA (CA24)	6700 - 10,000 R	3450 R
WILSON (DD408)	7600 R	4650 R
CONYNGHAM (DD371)	220 R	105 R
HUGHES (DD410)	4900 R	4275 R
BRISCOE (APA65)	6200 - 8000 R	3400 R
SALT LAKE CITY (CA25)	1600 - 2400 R	1700 R
MUSTIN (DD413)	2000 R	1600 R
TRIPPE (DD403)	4900 R	5200 R
DENTUDA (SS335)	340 R	320 R
LST52	4000 R	2000 R
LST220	41 R	86 R
LST545	145 R	14 R

It will be noted that four of the 15 unshielded badges or 25% of readings registered less dosage than some badge located inside the structure on the same vessel. On five vessels the unshielded dose was roughly twice the highest shielded dose. The badge recording the highest shielded dose on each of these vessels was generally located in the superstructure and the average plate thickness shielding the badge from the exterior incident radiation was between .2 and .3 inches. The thickness of steel required to reduce the incident radiation to 50% of the outside intensity is about .8 inches. Therefore, either the additional structure attached to the plating and the equipment in the compartment contributed about .5 inches of steel as shielding or the unshielded values are consistently high. On the remaining vessels having unshielded badges, the highest shielded dose varies from 10% on LST545 to 95% on DENTUDA of the unshielded dose.

15. Wide variations in badge readings are also observed in the data when a correlation is attempted between sister vessels of similar orientation to the burst. As an example the four destroyers in the northwest chain which had unshielded badges were selected. These were TRIPPE, 1320 yards; WILSON, 1766 yards; WAINWRIGHT, 2952 yards and CONYNGHAM, 3597 yards. A shielded badge common to all four vessels is located in the Bos'ns Stores, A-101-A, frame 4. The relation of readings from these badges to the unshielded reading is as follows:

Vessel	Unshielded dose	Bos'n Store dose	%
TRIPPE	4900 R	2600 R	53
WILSON	7600 R	2300 R	30
WAINWRIGHT	166 R	160 R	96
CONYNGHAM	220 R	72 R	32

The shielded dose varies from 30 to 96 percent of the unshielded dose. It should be noted that, contrary to expectations, the unshielded dose values do not decrease with increasing distance. WILSON appears to be in gross error. The shielded values show a more appropriate deterioration of radiation dose. This would indicate that shielded badges are less subject to extreme variations than those topside. Further investigation over a large number of target vessels indicates that badges well-shielded by structure or armor tend to give readings which are affected the least by differences in location and orientation of the badges. By taking these factors into account, it is anticipated that reasonable values of unshielded dose can be derived.

16. Document A lists, for each target vessel included in the document, an estimated value of unshielded dose. The basis for determining this dose is not evident. However, it is presumed that in general the values listed were obtained by study of the actual shielded doses registered on each vessel. Before attempting an independent assessment of the data, the general distribution of total radiation dose over the array as shown by these figures was investigated. Figure 7 is an accurate plot of the Test Baker array. The area over which the base surge passed is indicated by dashed lines. The unshielded dose, as determined from Document A, is shown by the name of each vessel. It will be noted first that many vessels are not listed in Document A. Some of these ships have no data because they were sunk as a result of Test Baker. But in addition to these, there are many omissions. Among the most important vessels upon which no data is available in Document A are GASCONADE, LST 133, YOG 83, PRINZ EUGEN and RHIND. A cursory perusal of the vessels on which data is available indicates three vessels: WILSON, NEVADA and RALPH TALBOT; the readings on which appear to be in gross error. WILSON, located between TRIPPE (5000 R) and STACK (3000 R) and at a rough equivalent radius as LST 52 (4000 R), appears to have a radiation measurement several thousand roentgen in excess of expectations. NEVADA (1600 R) is situated in the center of an area limited on four sides by MAYRANT (8000 R), TRIPPE (5000 R), LST 52 (4000 R) and LCT 818 (2000 R). Its value is much lower than might be predicted. RALPH TALBOT (2000 R) has the same dose as INDEPENDENCE which was on the same radius and about 400 yards closer to the burst. Vessels at equivalent distances as RALPH TALBOT are PARCHE (500 R) and BARROW (150 R). Therefore 2000 R would appear too high for RALPH TALBOT. As indicated in

previous paragraphs, other errors in total unshielded dose are to be expected throughout the area because of the uncertainty of the data but the errors in the values assigned these three vessels (underlined in blue in Figure 7) are particularly gross.

17. Figure 8 is an accurate plot of the Test Baker array with contours of total radiation based on the values shown in Figure 7. The three vessels underlined in blue and for which the radiation value appears to be in gross error have been ignored in drawing the contours. The other doses are accepted at face value for the time being. This data is, however, admittedly suspect and hence Figure 8 should be accepted on a qualitative basis only.

18. The principal characteristic shown by the Figure 8 contours is that the maximum radiation dose does not occur at the center of the array. The surface expressed by the contours is saddle-shaped, with the principal maximum located downwind in way of BRULE and MAYRANT. A secondary maximum exists in way of BRISCOE, with an apparent valley through the center of the array. The principal maximum is quite definite since both FALLON and PENSACOLA have lower values then BRULE. Upwind, the maximum is not as well defined since no radiation reading is available for GASCONADE. However, the values of NEW YORK, HUGHES and PENNSYLVANIA point rather definitely to a maximum in way of BRISCOE. Section A-A, shown at the bottom of Figure 8 indicates the distribution of radiation in an upwind-downwind direction.

19. Another remarkable feature of the Figure 8 contours is their tendency to be unsymmetrical with reference to the surface wind direction. The

direction of the surface wind, 150° true, was determined from observations of the base surge. The dashed lines in Figure 8 indicate the directional tendency of the base surge. Some of the radiation contours, particularly the 5000, 4000 and 3000 contours, seem to share this tendency. The 2000 and 1000 contours seem to favor the west side of the array downwind and the 7000 and 8000 R contours show a considerable orientation away from the surface wind direction. Section A-A, passed through the maxima, has a bearing of 138° true. If the radiation hazard was generated entirely by the base surge (paragraph 2), one would expect the total dose to be distributed symmetrically with reference to the wind direction. The fact that the distribution is unsymmetrical indicates that the dose was not obtained in so simple a fashion.

20. It is interesting to compare Figure 8 with the radiation distribution chart contained in Volume 1 of the Technical Director's report. This chart is Figure 5 of Enclosure (J) to the Technical Director's Report. The saddle-shaped character of the radiation distribution is not in evidence. A contour of "greater than 8000 R" surrounds the inner vessels of the array. All vessels inside the contour are labeled "greater than 8000 R". Comparison of total dose attributed to various vessels with those of Document A shows many variations. Document A is considered by AFSWP personnel to contain the most comprehensive data available. In view of the preliminary nature of the data on Figure 5 of enclosure (J), no particular meaning can be given to the absence of the saddle-shape, except that it may not have been anticipated by the group which analyzed the data. The orientation of total dose so as to favor the western side of the array is equally in evidence as in Figure 8. This trend thus appears to be well established.

21. In order to investigate the two unusual features of Figure 8, it is necessary to inquire into the manner in which the total dose was received. The total dose was received in two ways. The first way in which a dose was received was by means of direct radiation from radioactive particles in suspension in the base surge. This "surge radiation" operates on the particular film badge from the time the surge approaches close enough for the gamma radiation to penetrate to the badge until the base surge either retires downwind or lifts above the array, depending on the location of the badge. The remainder of the total dose registered by the film badge may be attributed to gamma radiation from fission products deposited on the exterior of the vessel. This "deposit radiation" operates on the film badge from the time the fission products begin to be deposited in the vicinity of the film badge until the badge is removed from the area, the intensity of radiation from a given amount of material decaying with time according to a known law. The dose from the surge and the dose from the deposit combine to form the total dose on the film badge. The total dose as recorded by the darkening of the film cannot be broken up into the two constituent doses. The deposit dose, however can be obtained independently of the film badge data by measuring the intensity of radiation at some time after contamination by means of a Geiger Counter or similar device. The deposit dose is obtained by integrating the area under a decay curve passed through the measured value, the limits being the time of deposit and the time the film badge was removed (or infinity, if the latter time is not known).

22. Data on the deposit dose, obtained in the above manner, is contained in Document B, obtained from AFSWP files. Document B contains the calculated deposit dose for certain target ships based on average topside Geiger readings taken from 2 to 29 days after Baker day. The details of assumptions made in the calculation are not available. Casual study of the data indicates some questionable values. For a first approximation of the distribution of deposit dose throughout the array, the data is accepted at face value for the time being. The resulting contours, however, should be accepted on a qualitative basis only. Figure 9 is a plot on an accurate Test Baker array of the data in Document B. Contours of intensity in roentgens are added. The double-peak or saddle-shaped distribution of radiation dose is again apparent. It is more strongly defined than in the total dose contours in Figure 8. The lower maximum in the upwind direction is especially well defined since a value is given for GASCONADE. Moving upwind from the center of the array, the values of deposit dose calculated are:

GASCONADE	1050 R
BRISCOE	1600 R
CATRON	2200 R
BRACKEN	585 R

There is obviously a well defined peak in the neighborhood of CATRON. This peak is not as firmly fixed in Figure 8 because of the lack of total dose information on GASCONADE. The contours of deposit dose in Figure 9 also shows a tendency to move toward the west side of the array, especially in the downwind sense. The eccentricity is more pronounced that that apparent in the total dose data (Figure 8).

23. Detailed observation of the deposit dose data in Figure 9 reveals several important facts. The deposit dose on NEVADA is 1980 roentgens as opposed to an alleged total dose of 1600 roentgens as indicated on Figure 7. The opinion stated in paragraph 16 to the effect that the total dose reading was in gross error is thus justified. In like manner, the deposit dose on Wilson is entirely in keeping with its location between TRIPPE and STACK. The total dose shown in Figure 7 is very probably in error. No deposit dose data is available on RALPH TALBOT. One point of interest is the extremely low deposit dose readings on INDEPENDENCE, PENSACOLA and SKATE. These values will be scrutinized closely.

24. Before proceeding to an independent analysis of gamma radiation with the object of obtaining more accurate values than those contained in Documents A and B, it is worth-while to plot the distribution of surge radiation over the array. This is accomplished by plotting the difference between total dose and deposit dose on the ships where these values are available. Values for NEVADA, WILSON and DAWSON, which are suspect, are omitted. The results are shown in Figure 10. Contours of surge radiation intensity have been added. Since these curves are based on the highly doubtful practice of comparing two sets of unrefined data, they cannot be considered as representing more than a rough qualitative approximation of the effect of radiation from the base surge. Nevertheless, Figure 10 substantiates the results of the photographic analysis of the base surge movement to a remarkable degree. The contours, roughly paralleling the envelope of the base surge, fit the admittedly few points available very satisfactorily. The axis of symmetry of the contours corresponds to the wind direction assumed for the surge (150° true). Section C-C passed through the wind axis reveals the single peaked distribution of radiation

which might be expected. The peak is slightly upwind of the center of the array. This characteristic can be rationalized as the natural result of the retirement of the base surge over the upwind side of the array at an earlier time than over the downwind sector. The decay of radiation is exponential and so rapid that the time after detonation at which radiation is first received is more important than the time spent in the radioactive area. This fact also accounts for the sharp rise of the radiation dose to the maximum.

25. Certain provisional qualitative conclusions can be derived from the foregoing analysis of the data in Documents A and B:

(a) The distribution of radioactivity over the Test Baker array was not a single-peaked surface with a maximum at the point of detonation. The surface of distribution was saddle-shaped with the principal maximum downwind in the neighborhood of BRULE. A secondary maximum occurs upwind in the neighborhood of BRISCOE.

(b) The double-peaked shape of the surface of distribution of total radiation dose is apparently due solely to the dose received from the fission products deposited upon the target array. The double-peaked character of the distribution of deposit dose was strongly indicated by measurements of contamination following the test.

(c) The distribution of total dose is not symmetric with the envelope of the base surge. This indicates that, assuming the base surge envelope to be correct, the total dose did not result entirely from the base surge as stated in paragraph 2. The eccentricity of total dose distribution is toward the west side of the array. Studies of Document B indicate that the eccentricity of total dose distribution was due solely to the influence of the deposit of fission materials on the targets. Again, the tentative conclusion is that the mechanism by which the fission products were deposited upon the target array cannot be explained solely by the movement of the base surge.

(d) The residual radiation dose, which when added to the deposit dose equals the total radiation dose, was apparently due to radiation emanating from the base surge. The distribution of residual or base surge radiation was a single-peaked surface with the maximum roughly at the center of the array. The orientation of the base surge radiation distribution apparently substantiates the studies on the motion of the base surge.

26. Following qualitative estimates of the distribution of gamma radiation dosage after Test Baker, it remained to recalculate the data so as to obtain the best quantitative estimate of gamma radiation distribution consistent with the accuracy of the basic readings. This step was necessary because the calculations made previously showed grave inconsistencies and uncertainties. It was decided to investigate first the distribution of deposit doses as calculated from Geiger Counter readings made subsequent to Test Baker.

27. The basic assumption made in determining the deposit dose was that the radiation from deposited fission products diminished with time according to a decay law of $T^{-1.3}$. That is, $\frac{d_1}{d_2} = \left(\frac{t_2}{t_1}\right)^{1.3}$ where d_1 is the radiation intensity at time, t_1, after deposit and d_2 is the radiation intensity at time, t_2. Figure 11 shows a curve AB which corresponds to the 1.3 decay law. Ordinates are radiation intensities in roentgens per day while abscissae are time

(zero time is fission). Let t_1 be the time at which deposit occurs. For purposes of this study, time of deposit, t_1, is considered identical with time of contact as listed in Figure 1, rather than time of engulfment or some arbitrary time subsequent to engulfment. This assumption is based on photographic evidence that the face of the base surge formed an acute angle with the surface of the water so as to overhang by several hundred yards the extent of the base surge at the surface. It appears that rain-out of fission products on the target vessels began prior to engulfment. The fact that several target vessels received considerable topside deposit although never actually engulfed by the surge (for instance, CARTERET, LCT 1013, LCT 1078) gives strong support to this assumption.

28. Geiger readings obtained subsequent to Baker Day on the target vessels represent values of gamma radiation intensity d_2 at a time t_2 subsequent to time of deposit, t_1. Given values of d_2, t_2 and t_1 it is possible to calculate the integrated dose received from t_1 to infinity. This is the deposit dose and corresponds to the area under AB (Figure 11) from t_1 on to infinity. If d_2 is the average topside reading on the target vessel, the integrated dose D can be considered as the average deposit dose experienced by the vessel. The expression for D is derived as follows:

(1) $$\frac{d}{d_2} = \left(\frac{t_2}{t}\right)^{1.3}$$ where d_2 is the average topside Geiger reading at time t_2.

(2) $$D = \int_{t_1}^{\infty} d \; dt$$

from (1), $$d = \frac{d_2 t_2^{1.3}}{t^{1.3}}$$

Substituting for d in (2),

$$D = \int_{t_1}^{\infty} \frac{d_2 t_2^{1.3}}{t^{1.3}}\, dt = d_2 t_2^{1.3} \int_{t_1}^{\infty} \frac{dt}{t^{1.3}}$$

Integrating,

$$D = d_2 t_2^{1.3} \left[\frac{1}{-0.3\, t^{0.3}} \right]_{t_1}^{\infty} = \frac{d_2 t_2^{1.3}}{-0.3} \left[0 - \frac{1}{t_1^{0.3}} \right]$$

(3) $$D = \frac{d_2 t_2}{0.3} \left(\frac{t_2}{t_1} \right)^{0.3}$$

d_2 = Geiger reading at t_2 in roentgens/day

t_2 and t_1 = time in days subsequent to fission.

For purposes of this study, the above expression is modified as follows:

(4) $$D = \frac{d_2 t_2}{0.3} \left(\frac{t_2 \times 10^5}{t_1 \times 1.158} \right)^{0.3}$$

where d_2 is in R/day, t_2 is in days and t_1 is in seconds.

29. The principal sources of d_2 and t_2 values for the above expression were (a) the Interim Baker Decontamination Report compiled by the Bureau of Ships Group, (b) Table 1 of Appendix VII to the B2 report from 013E to 013 dated 25 September 1946, and (c) detailed daily reports of Geiger readings available in Bureau of Ships files. An effort was made to obtain as many bonafide readings as possible. For each reading a deposit dose in roentgens, assuming that the particular reading had been arrived at along the 1.3 decay durve, was calculated using expression (4). The most

probable value of deposit dose was estimated from an assessment of the various deposit doses predicted by the readings. The estimate was not generally an average of the various predicted deposit doses. Readings which were supported by several sources and which appeared to reliably represent the original deposit were weighted. The principal factor affecting the reliability of the Geiger readings was the decontamination procedure used after Test Baker. Decontamination evidently had a much higher priority than attempts to gather technical data on contamination. As a result, many targets were washed down before any readings were taken. Decontamination had a highly variable effect on deposit readings, ranging from practically nil (SKATE) to more than a factor of 2 (MUGFORD). Consequently, readings obtained before decontamination were more reliable than later readings. Other factors which affected reliability of readings were the extent of readings over the topside, the manner in which "hot spots" were averaged in the overall reading, and the condition of the decks as to rust, sand, etc. Due weight was given to all limitations on the data in arriving at the most probable deposit dose. In order to qualify the dose thus selected as to the reliability of the data from which it was derived, an "accuracy evaluation" has been assigned each result. These evaluations range from A to E and are defined as follows:

A	within ± 10%
B	within ± 25%
C	within ± 50%
D	No statistical significance (single points or widely spaced points)
E	suspected data

It is important to note that all doses recorded by Geiger Counter measurements are of gamma radiation only. Beta particles were not measured.

30. The results of the deposit dose calculations are shown in Figure 12 (A to F). This tabulation is self-explanatory. The results of the two right hand columns of Figure 12 are plotted on an accurate Test Baker array in Figure 13. The area swept by the base surge is indicated by a dashed line. Contours of deposit dose based on the values plotted in Figure 13 have been represented in Figure 14 so as to avoid over-complication of Figure 13. Several important characteristics of the distribution of deposit dose are apparent at once from casual study of Figure 14. Most prominent is the fact that at least four maxima are evident. The qualitative study represented in Figure 9 indicated only two peaks. That a hollow or saddle exists in the center of the array is still apparent, however. This is, perhaps, the most important characteristic of the deposit dose distribution. A third characteristic of the contours of Figure 14 is that an orientation of the deposit distribution toward the western side of the array is no longer in evidence and has been replaced, apparently, by an orientation to the eastward downwind. There are, however, certain limitations on the data which must be analyzed in order to arrive at a true picture of the distribution of the deposit dose.

31. The data represented in Figures 12 to 14 constitutes the best quantitative estimate which can be made with the data obtained at Bikini as to the actual deposit dose experienced by the Test Baker target array. All known data on this problem was used in the calculations of Figure 12. The accuracy of the result is indicated by the evaluations assigned each value. Of 47 vessels receiving a deposit dose of 25 roentgens or more, 28 were assigned an accuracy evaluation B (± 25%), 10 were assigned an accuracy evaluation A (± 10%) and the remainder (nine vessels) received

an evaluation of C or D and can be considered statistically indeterminate. No suspected values (evaluation E) resulted. In addition, the contours of Figure 14 are weighted toward the A and B evaluated points. Consequently, the contours of Figure 14 represent the actual distribution of deposit dose after Test Baker to within a few percent.

33. The actual deposit dose experienced by the target vessels after Test Baker is not of primary interest in this study. What is required is the distribution of deposited fission products over the area affected by the detonation. If the adsorption characteristics of the target ship surfaces were in all cases identical, the distribution of deposited fission products would be identical with the distribution of actual deposits experienced by the target vessels. It is well-known to personnel who inspected the targets after Test Baker that the condition of exposed surfaces varied greatly throughout the array. Consequently, the contours of Figure 14 include a distortion resulting from variations in the ability of target ship surfaces to collect and hold the fission products. It does not appear possible to correct for this distortion on each vessel in the array due to lack of data on the exact condition of each target, and, more important, because of lack of concrete information as to the adsorption characteristics of various surface conditions. Recent detail monitoring of CRITTENDEN at San Francisco Naval Shipyard has revealed important information on this subject which enables a reasonable correction to be made. The following is quoted from the report on Project 41-47 of 29 September 1947 concerning experimental monitoring of CRITTENDEN:

(a) Contamination collected in low spots and places where drainage was bad.

(b) Rusty areas retained more contamination than painted areas.

33. Careful study of the detailed monitoring of CRITTENDEN indicates that variations of contamination over various surfaces was only significant in way of rusty, poorly drained surfaces. Readings in such locations were higher by a factor of about three. Therefore, as a first approximation, the variation of adsorption characteristics among target ships can be discounted except for vessels whose external surfaces were rusty and poorly drained. Bureau of Ships inspections indicate that one target type, the LST, belonged in this category. LST 661 was especially rusty. Further, LST decks are poorly drained. It is considered, therefore that the maxima shown on Figure 14 in way of LST 52 and LST 661 is entirely due to increased adsorption of fission products by the deck surfaces. If the deposit dose assigned LST 52 (6000 R) is compared with CRITTENDEN (2750 R) and PRINZ EUGEN (1750 R) on the opposite side of the array the equivalent deposit dose for LST 52 would appear to be about 2500 R. Similarly, the equivalent dose on LST 661 should approximate MUGFORD (1500 R) and that on LST 220 should equal CONYNGHAM (100). It will be noted that these reductions are by a factor of 2.5–3 which is in good agreement with the experimental evidence. Figure 15 shows contours of deposit dose resulting when deposit doses on the LST's are arbitrarily reduced to the amounts indicated in brackets.

34. Several vessels other than LST's had exterior surface conditions sufficiently at variance with the majority of targets to make the fission product deposit represented by their deposit doses open to question. For instance, it has been established that porous materials collected

contamination more efficiently than non-porous materials. The concrete drydock, ARDC-13, being more porous than steel vessels, probably received a greater deposit dose than would have been received by a steel vessel at the same location. However, since the 3250 roentgen dose received by ARDC-13 has an accuracy evaluation of D, it is idle to attempt a reduction because of porosity, especially since the effects of porosity have not been evaluated quantitatively. Similarly, the value recorded on INDEPENDENCE has also been left unchanged, although it probably is somewhat high due to the poor drainage characteristics of the upper surfaces resulting from severe Test Able damage. The probable variation in deposit dose recorded on the above vessels is judged to lie within the range specified by the assigned accuracy evaluations.

35. It remains to investigate the reasons behind the configurations shown by the curves in Figure 15. There appear to be two major and one minor maxima established by the contours. All three peaks occur over a radial range of 500 to 1000 yards, centered approximately on the 1000 yard circle. After considerable study and the investigation and rejection of several unsuitable hypotheses, it was determined that the peaks evidenced on Figure 15 coincide spatially with the location of the early fallout from the mushroom head as shown by photographs. It was also established that the height of the peaks agreed generally with the time of the fallout. That is, the fallout in the vicinity of BRULE - PENSACOLA was earlier than that in the vicinity of GASCONADE, etc. Figure 16 through 19 depict the principal data which can be obtained from photographs. The earliest fallout from the mushroom is not over BRULE - PENSACOLA, the "hottest" vessels in the array. Figure 17

definitely establishes that the earliest fallout fell into the southern sector of the array between PENNSYLVANIA and SKATE. This area should be the sector showing the greatest deposit dose in the array, if the hypothesis is true. Unfortunately, no vessels were located in this sector and thus the hypothesis loses a certain amount of substantiation. The remaining fallouts provide a good measure of information. The western deposit occurs first and extends from PENSACOLA to YOG 83. Although contact with the surface is hidden by the base surge, the time of contact can be estimated roughly as about one minute after burst. The fallout over GASCONADE falls shortly thereafter. It is important to note that at times approximately one minute after burst, a time difference of ten seconds in the two times of fallout is equivalent to a 20-25% reduction in radiation intensity according to the $T^{-1.3}$ law. For contribution to deposit dose, however, the time difference has the one effect of changing the time of deposit, t_1, since the deposited and undeposited products are aging at the same rate. This time delay is too short to account fully for the difference in deposit dose in the two fallout areas. Apparently, the earlier fallouts contain a greater amount of fission products then somewhat later fallouts.

36. A second rough substantiation of the argument that the fallout from the mushroom head contributed a considerable proportion of the contamination deposited upon the target vessels can be had by observing in which sectors there was a conspicuous absence of fallout or very much delayed fallout. The most prominent "hole" in the fallout ring as observed by study of photographs is the vicinity of NAGATO and SALT LAKE CITY (See Figures 17 and 18). A secondary "hole" in the vicinity of SKATE is noted in Figure 16. Both these areas show moderate deposit doses compared to the peaks under fallouts.

37. Based on the hypothesis that deposit doses were greatly enhanced in way of the fallout "ring" from the mushroom head, the distribution of deposit dose over the target array can be visualized in three dimensions as having a shape comparable to a volcanic mountain containing a crater in the center. The fallout ring produces the rim or wall of the crater. This rim is not smooth but consists of several peaks and valleys around its perimeter corresponding to the unequal times and amounts of fallout. The center of the crater and rim is not the center of the array. Downwind, in the neighborhood of BRULE, YOG 83, MAYRANT and NEVADA, the mean distance from the center of the array is about 1000 yards. Upwind in way of GASCONADE, the mean distance to the center is but 600 yards. PENSACOLA, crosswind, is about 800 yards from burst. The fallout ring is thus about 1600 yards mean diameter, displaced downwind from LSM 60 about 200 yards. Since the mean time of fallout is estimated to be about one minute, the velocity of movement downwind of the mushroom must be about 200 yards per minute or 10 feet per second. This corresponds to a speed of six knots or surface wind speed. This motion of the mushroom is substantiated by studies of photographic evidence.

38. Figure 20 shows the rim circle or mean circle of the fallout from the mushroom in elevation and in expanded form, that is, broken at 0° true and laid out flat to demonstrate the contour of the crater rim. Ordinates are deposit dose values while abscissae are true compass bearings from the array center. Locations of target vessels on or near the rim circle are indicated. Portions of the profile which are fairly well fixed by specific target ship doses are represented by a solid line. In certain sectors of the circle, data on the shape of the contour is incomplete

because of gaps in the spacing of the target array. These sections are indicated by a dotted line. In addition, probable profiles in the uncertain sectors, as indicated by studies of the fallout pattern, are represented by a dashed line. Figure 20 shows probable profiles in two sectors. The peak represented by the earliest fallout, which did not contact any targets, is shown between 180° true and 220° true. The maximum value has been estimated at 8000 roentgens from comparison with known values of PENSACOLA and BRULE. A probable minimum deposit in way of NAGATO, which was not measured, is shown at 30° to 40° true. This valley is estimated at 1000 roentgens by observations of the "hole" in the fallout ring from photographic evidence and a low value of deposit on LCT 818.

39. The shape of the fallout ring profile shown in Figure 20 demonstrates the irregular nature of the deposit from the fallout. For design purposes, an average expectancy or mean value of deposit dose in way of the fallout is necessary. This mean deposit dose, which gives an area equal to the area under the profile in Figure 20, is 3924 roentgens. A horizontal line representing this dose is shown on Figure 20. For design purposes, 4000 roentgens is a convenient value for the average expected deposit dose to be experienced by a vessel stationary on the rim circle or mean location of the fallout ring. This would be the maximum deposit to be expected under design conditions.

40. An approximate measure of the deposit dose of the center of the array can be calculated from a Geiger reading obtained by aircraft at burst plus one hour. The intensity of radiation near the water surface at the center of the array was 400 roentgens per 24 hours at this time. Assuming that the deposit occurred one second after burst (it was probably

later when the surface subsided) the integrated deposit dose from expression (4) is 650 roentgens. This indicates the depth of the "crater" in the center of the deposit dose distribution. The deposit dose of the center of the array is shown as a horizontal line on Figure 20.

41. In summary, Figure 14 represents the best quantitative data available to the Bureau of Ships on the actual distribution of deposit dose on Test Baker target ships. Figure 15 represents the best quantitative data available to the Bureau of Ships on the distribution of deposit over the array after certain elementary corrections are made for the variations in ability of target ship surfaces to absorb fission products. Studies of photographic records indicate that the maxima in Figure 15 correspond with early fallout from the mushroom head. It is hypothesized that these maxima are indeed the result of contamination from the fallout and that, ideally, the contamination would be in the form of a ring of high deposit values. Actually, the deposit values in the ring are highly variable and form an annular series of maxima and minima. Considerable accurate analysis by persons skilled in photogrammetry is necessary to explore this hypothesis and to determine the space, time and rate of fallout factors which control the deposit dose received.

42. Analysis of the total dose of gamma radiation experienced by the target ships is based on the film badge data recorded in Document A. The principal data from Document A is reproduced in Figure 21 (A to K). This represents the best and most complete information obtainable from the files of AFSWP. All measurements are of gamma dosage only, which is consistent with the deposit dose calculation previously made. Nearly all

readings are of shielded badges; that is, badges located within the target so as to be protected to a greater or lesser extent by structure and equipment. The influence of the shielding on the badge reading is not understood quantitatively as yet. It apparently is many times the shielding effect which might be expected from consideration of the plating thicknesses interposed between the badge and the exterior of the vessel. The problem of determining the effective shielding of ships' structure will be the subject of a separate study.

43. Sixteen film badges on thirteen targets were located topside in presumably unshielded locations. Paragraphs 13, 14, and 15 state the reasons why the reliability of these badge readings is open to question. Consequently, the actual total dose experienced by each target vessel must be estimated largely from comparison with other targets having badges in similar locations. Certain targets whose total dose is considered to be well established will be used as key targets or "bench marks" from which to measure the total dose received by neighboring vessels or vessels of similar type. Deposit doses recorded in Figure 12 will enable a minimum value of total dose to be established in nearly all cases. As was the policy in estimating deposit dose, an accuracy evaluation identical to that established in paragraph 29 will be placed on each estimated total dose to indicate the reliability of the estimate. All estimates will be of unshielded total dose experienced by the targets. It should be noted that film badges were taken off the targets during a period of weeks following the test. Deposit doses were calculated to infinity as regards time. In this study the film badge results will be taken as the total dose to infinity in regard to time since the "tail" of the curve

of radiation from the deposit beyond several days does not contribute appreciably to the total dose.

44. It is essential to a comparison analysis of the total dose that certain datum vessels exist, for which the required values of the total dose are known with reasonable certainty. Otherwise there would be little quantitative significance to the film badge results. The actual film badge readings are highly relative because of undetermined shielding effects and certain problems of converting the badge densities to roentgen readings. Fortunately, several target vessels can be used as datum vessels for the rest of the array. In general, these vessels are remote from the center of the array and downwind. Because of the early lifting of the base surge, these vessels never actually disappeared into the surge but were merely rained upon from above. Consequently, the deposit dose and total dose should be nearly identical. The following targets were investigated first to establish accurate total dose values, if possible:

(a) LST 545.

This ship was the outermost downwind LST (see Figure 13). It never disappeared from view of towers on Bikini and Amoen as the base surge passed over it. The estimated deposit dose was 150 roentgens (Figure 12-D). An unshielded badge on the starboard lookout recorded 145 roentgens total dose. This is an excellent check and the estimated total dose was set at 150 roentgens, accuracy evaluation A.

(b) CONYNGHAM (DD 371)

This vessel was the outermost vessel in the north-west destroyer chain. It never disappeared from view as the base surge passed over it. Consequently, the total dose would be expected to agree substantially with the estimated deposit dose. The estimated deposit dose was 100 roentgens (Figure 12-C). An unshielded badge on No. 1, 5-inch gun mount registered 220 roentgens. This reading is considerably higher than might be expected. On the basis that deposit dose might be as high as 125 - 150 roentgens, a total dose of about 150 roentgens would be more in order. The highest shielded reading recorded was 105 roentgens in the pilot house. This appears reasonable. However, because of the variations in badge readings on CONYNGHAM, the data does not warrant using this vessel as a "key" target ship.

(c) LCT 1078

This craft lay just outside the path of the base surge in the north-east LCT chain. It was rained upon by the overhanging portion of the base surge. The estimated deposit dose was 100 roentgens (Figure 12-E). A badge in the pilot house registered 102 roentgens. The pilot house on an LCT is nearly transparent to gamma radiation. In addition to the deposit dose, LCT 1078 undoubtedly received some "surge radiation" from the base surge which passed within 200 yards of the vessel. On this basis, a total dose, unshielded, of about 125 roentgens appears to be a reasonable figure. An accuracy evaluation of B, comparable to that of the deposit dose estimate, is justified.

(d) LCT 705

LCT 705, situated outside the path of the base surge on the west side of the array received a deposit dose of 25 roentgens from the overhanging portion of the base surge. The radiation from the base would have been comparable to that experienced by LCT 1078. A badge located in the pilot house registered 40 roentgens. On the basis of the same considerations as (c), a total dose of 50 roentgens with accuracy evaluation of B is assumed.

(c) TRIPPE (DD403)
HUGHES (DD410)

These two destroyers were located in different sectors of the array, TRIPPE in the northwest destroyer chain and HUGHES on the east side of the array. Badge readings strongly indicate that these vessels sustained identical total doses from Test Baker. The principal supporting badge readings are as follows:

	HUGHES	TRIPPE
UNSHIELDED BADGE	4900	4900
BOS'N'S STORE	2600	2600
No. 1 HANDLING ROOM	1800	1925
GUNDIRECTOR	4275	3900

These figures indicate that a total dose of about 5000 roentgens would be reasonable for both vessels. Principal discrepancies in the data are:

	HUGHES	TRIPPE
TORPEDO SHACK	1750	5200
GAS MASK STOWAGE	470	1750

The torpedo shack value on TRIPPE is higher than the unshielded badge and is open to question. The discrepancy in doses in the gas mask stowage in the stern may be explained by the flooding of the stern of HUGHES. In view of the close agreement among the film badges supporting the estimate, a value of 5000 roentgens is assumed, with an accuracy evaluation of B.

45. The vessels investigated in paragraph 44 are the only targets for which a firm judgment of total unshielded dose can be made at the outset of the study. Further estimates must be obtained by comparing various

target vessels with adjacent ships or ships of similar class. Fortunately, a large number of the target ships were placed in "chains" of like vessels extending out from the center of the array like spokes of a wheel. These "chains" are ideally suited for comparative analysis of total unshielded dose. Investigation of each chain had the following results:

(a) Northwest Destroyer Chain.

Data on the northwest destroyer chain is plotted in Figure 22. Ordinates are dose in roentgens. Abscissae are distance in yards from center of burst. The location of the eight destroyers in the chain are indicated. Curves have been drawn through points representing badges in substantially identical locations on each ship. The location of the badge is indicated on the curve. In addition, a curve of estimated deposit dose has been shown. With the aid of these curves and the unshielded check point of 5000 roentgens previously estimated for TRIPPE, a curve of estimated total doses has been drawn. The unshielded total dose estimates taken from this curve are as follows:

		ACCURACY EVALUATION
MAYRANT (DD402)	8000 R	C
TRIPPE (DD403)	5000 R	B
WILSON (DD408)	3800 R	B
STACK (DD406)	3200 R	B
RHIND (DD404)	2700 R	C
MUGFORD (DD389)	1750 R	B
WAINWRIGHT (DD419)	500 R	B
CONYNGHAM (DD371)	125 R	B

An accuracy evaluation of B has been given these values with the exception of two cases. The dose estimated for MAYRANT has been given a C evaluation because of the difficulty in assessing the reading of film badges at very high levels of radiation (greater than 8000 roentgens, roughly). The total dose on this vessel may be somewhat higher than estimated as a consequence. The RHIND estimate has a reduced accuracy evaluation because of the lack of supporting badge readings on this vessel. Study of the character of the curves in Figure 22 is most instructive. It will be noted that the curves for badge locations below the weather deck reflect the strong influence of the deposit dose characteristics. However, the downsweep of the deposit dose curve from TRIPPE to MAYRANT has disappeared or is greatly reduced by the effects of the "surge radiation" which, within about 1200 yards becomes more intense than that emanating from the deposit. It will also be noted that the curve for the director, which is remote from the deposit-laden decks and more exposed to the surge radiation, follows the total dose curve very closely except at ranges beyond 3000 yards where the surge radiation has become very small due to the lifting of the base surge. In this region, the very remoteness of the director from the mass of deposited material causes its dose to fall off more rapidly than the average.

(b) Western APA Chain.

Data on the western APA chain is plotted in Figure 23. The dose-distance grid is identical to that in Figure 22 and the target ships involved are indicated at their proper distance from the burst. As in Figure 22, the curve of estimated deposit dose is shown. No "key" vessel exists in this chain to act as a check point. Consequently, the characteristics of the curves depicted in Figure 22 for the northwest destroyer chain are relied upon to indicate the proper curve of estimated total dose. Estimated total doses taken from this curve on Figure 23 and rounded off in view of the accuracy involved are as follows:

		ACCURACY EVALUATION
FALLON (APA81)	10,000 R	C
BRULE (APA66)	9,500 R	B
DAWSON (APA79)	6,700 R	B
CRITTENDEN (APA 77)	3,000 R	B
BARROW (APA61)	1,500 R	B
BANNER (APA60)	700 R	D
BUTTE (APA68)	400 R	B
CARTERET (APA70)	130 R	B
CORTLAND (APA75)	10 R	B

Inasmuch as the film badge data and deposit dose data is estimated to be sufficiently accurate to give results within ± 25% of the correct values, an accuracy evaluation of B is given with two exceptions. No topside unshielded or lightly shielded badge readings are available on FALLON. Hence, the curve has been influenced in this region by the behavior of the destroyer curve in Figure 22. However, the drastic down-sweep of the shielded curves depicted in Figure 23 indicate that the surge radiation was less effective in this quadrant and hence, FALLON's total dose may be considerably lower than estimated. A lower accuracy evaluation is made to indicate this possibility. Fairing of the deposit dose curve indicated that the deposit estimate for BANNER was much too high. Figure 12-B indicates that the estimate of 1000 roentgens deposit dose made for BANNER was made on the basis of three geiger readings, two of which gave deposit doses in the neighborhood of 1000 roentgens. The third gave a much lower dose, 659 roentgens. The curve in Figure 23 indicates that the third reading was more representative of the actual deposit dose. The curve of deposit dose shown in Figure 23 is estimated to be quite reliable in this region because of the accuracy of the estimate for BARROW and BUTTE, vessels adjacent to BANNER in the chain. On the basis of these considerations and in order to maintain a consistent relation between deposit and total dose for each vessel, the estimated deposit dose for BANNER has been changed to 600 roentgens and the accuracy evaluation lowered to D. A total dose estimate of 700 roentgens is made and an accuracy evaluation of D placed upon the estimate in view of the conflict with the original deposit estimate. The characteristics of the curves in Figure 23 reflect, in general, the same influences noted on the destroyer curves (Figure 22). Badge locations below the weather deck reflect the character of the deposit dose curve while the wheelhouse badges tend to approach the total dose curve in the close-in region where surge radiation becomes of paramount importance. In addition, the twin curves of badge locations in the S.D. Stores compartment, frame 20, give very interesting information on the transparency of the sides of the vessel to gamma radiation. One set of badges was located on the port sides of the compartment and the other on the starboard sides. Thus, in addition to a common dose received from radiations from overhead, each set of badges reflects a dose received through the adjacent shell plating. It will be noted in Figure 13 that this chain of APA's were so situated that the center of the burst was on the port side. From the outermost vessel in toward the center, the port badge readings are consistently above the starboard badge readings, indicative of the radiation received from the face of the base surge as it approached the port side of each vessel. Beginning at 1800 yards approximately and progressing in toward the center of the array the port side doses begin to increase abruptly, rapidly drawing away from the starboard side badge readings. The port badge reading on DAWSON was 1880 roentgens while the starboard badge reading was only 495 roentgens. This indicates that some other effect has been added to the base surge radiation on the port side of the DAWSON. Paragraph 35 demonstrated that an early fallout from the mushroom cloud fell on the port side of DAWSON in the neighborhood of BRULE. It was postulated that this fallout was highly radioactive. The radiation from this fallout would account for the radically increased port badge reading on DAWSON. This hypothesis is supported by the character of the curves at closer ranges. At BRULE, the two curves have approached again, indicating that the fallout fell all around BRULE leaving only the radiation from the face of the base surge to have its selective effect on the port badge. FALLON was inboard of the BRULE fallout so that it fell on her starboard side. As a result the curves cross between BRULE and FALLON, the starboard badge then recording the higher reading. Apparently the radiation from the BRULE fallout was more intense on FALLON than the radiation from the approaching face of the surge. This demonstrates that the fallout over BRULE was very "hot" and supports the hypothesis investigated in paragraph 35 and subsequent paragraphs.

(c) Southern APA Chain

Data concerning total dose distribution along the southern APA chain is plotted in Figure 24. The data is rather meager because only four ships had significant doses and no badge readings were available on one of the most important of these, GASCONADE. Also, badges were not placed in identical locations on all vessels and as a consequence only four shielded curves could be drawn. The badge readings in the wheelhouse were available on CATRON and BRACKEN only. However, BRISCOE had a badge in the Dental Office on the upper deck at Frame 105. This badge location would be roughly equivalent to the wheelhouse location. BANNER, in the western chain, had badges in both locations which registered substantially the same dose. Assuming that the locations are comparable, the dose recorded in the Dental Office has been plotted on the wheelhouse curve for BRISCOE. On the basis of the character of the shielded curves and the estimated deposit dose curve, a curve of estimated total dose has been drawn. Two unshielded badges on BRISCOE have been used as check points, the curve being passed midway between their values. The estimated total dose for each vessel, as taken from this curve are:

		ACCURACY EVALUATION
GASCONADE	9000 R	C
BRISCOE	7000 R	B
CATRON	3500 R	B
BRACKEN	1500 R	B
FILLMORE	10 R	B
BLADEN	Negligible	
GENEVA	"	
NIAGARA	"	

The estimated dose for GASCONADE is given a reduced accuracy evaluation because of the lack of film badge data on this vessel. The character of the curves in Figure 24 reflect the influences noted on previous chains. The below-decks badges show the strong influence of the deposit while the wheelhouse curve tends to follow the total dose curve, illustrating the increased influence of the surge radiation in the close-in region. Unfortunately, no badge readings are available on GASCONADE so that it is impossible to check the shape of the deposit dose curve in this region. The hump in the deposit dose curve is due to the local fallout in way of GASCONADE. Since this chain extends upwind, there was no tendency for the fallout to extend its influence to vessels further out the chain.

(d) Northeast LCT chain. The data available regarding the total dose experienced by the northeast LCT chain is plotted in Figure 25. The LCT, being a light, uncomplicated craft, is fairly transparent to gamma radiation. The curves representing badges in the Bos'n locker and crew's quarters thus give an excellent clue to the nature of the total dose curve in the region beyond 1500 yards. The two curves are substantially identical and indicate that the observations were of high quality. The engine room, although considerably transparent to the surge radiation, shows the strong influence of the deposit and gives a fair check of the deposit curve in this region. The sharp rise in the deposit curve from LCT 818 to LCT 816 is due to the fallout over the latter ship. The LCT 816 deposit dose is corroborated by the dose on LST 133, a close neighbor in the array. No badge readings are available for LCT 816. As a consequence, the accuracy evaluation of the total dose for this vessel is reduced. The total dose estimates for the LCT chain are as follows:

		ACCURACY EVALUATION
LCT 816	5200 R	C
LCT 818	3000 R	B
LCT 874	850 R	B
LCT 1078	120 R	B
LCT 1112 and 1113	10 R	A

 [redacted]

The leveling off of the total dose in the region beyond 3500 yards is due to a fairly constant dose received from contaminated surface water which eventually affected the waterline area of LCT 1112 and LCT 1113.

(e) Northern LST Chain. Data concerning the distribution of total dose in vessels of the LST Chain are plotted in Figure 26. Evaluation of this data is complicated to a certain extent by the abnormal deposit which these vessels are believed to have received. In paragraph 33, deposit values for the LST chain are altered to give a more accurate picture of the distribution of deposited fission products over the array. In Figure 26, curves are plotted for deposit dose under both conditions. The plotted values for badges in the auxiliary machinery space and bilge control room result in similar curves. Both of these locations are below the tank deck and reflect the strong influence of the deposit dose. The actual values should be compared with the curve of actual deposit dose. Equivalent curves based on the adjusted deposit dose curve would be similar in shape but with reduced ordinates. The badge in the general stores compartment was located in a wing compartment and apparently reflects the influence of the surge radiation to a much greater extent. In fact, the general stores curve agrees closely with the character of the estimated total dose curve. The end-points of the total dose curve are fixed by unshielded badge readings on the look-out platform on LST 52 and LST 545. This location is sufficiently remote from the rusty weather deck to give valid readings. The existence of the unshielded check-points makes the quantitative accuracy of the total dose fairly high and also offers a good check on the reasonableness of the adjusted deposit assumptions. Estimated total doses for the LST chain are as follows:

 [redacted]

		ACCURACY EVALUATION
LST 52	4000 R	B
LST 661	1750 R	B
LST 220	275 R	B
LST 545	150 R	A

46. Determination of total dose on vessels not lying in a chain of similar vessels requires individual study and comparison. This is most easily accomplished on vessels where estimates have already been made for sister or similar ships in chains. Destroyers not lying in chains are HUGHES, MUSTIN, and RALPH TALBOT. The total dose on HUGHES has already been established at 5000 roentgens (paragraph 44). MUSTIN had an unshielded badge which registered 2000 roentgens. To test this value, comparison is made with badge readings on MUGFORD, for which a total dose of 1750 roentgens (B evaluation) has been made.

Compartment	MUSTIN	MUGFORD
Inside No. 1 Mount	1600	1750
No. 1 Handling room	235	190
Bosn's Stores	1600	420
No. 1 Magazine	79	36
Deposit estimate	1000	1500

The MUGFORD reading inside No. 1 mount is probably in error since it is identical with the total dose estimate. On the basis of other considerations a total dose for MUSTIN of 2000 roentgens appears to be quite reasonable. An accuracy evaluation of B is made. Badge readings on RALPH TALBOT appear to be slightly higher than those on MUSTIN in a very consistent manner that warrants a total dose estimate of 2250 roentgens, accuracy evaluation B.

47. No badge readings exist for LST 133 but inasmuch as this craft was very close to LCT 816 and the two vessels sustained the identical deposit dose, an estimate of total dose of 5000 roentgens, accuracy evaluation C, is made, agreeing with that for LCT 816. Comparison of other landing craft with craft as similar construction and location resulted in the following estimates:

		ACCURACY EVALUATION
LCT 1013	250 R	B
LCT 1115	Negligible	C
LCT 332	750 R	C
LCI 327	350 R	C
LCI 329	10 R	C
LCI 549	Negligible	C

48. Battleships. Badge readings on the three surviving battleships are very misleading unless analyzed carefully. This stems from the fact that badge locations on PENNSYLVANIA were generally high in the vessel and received large doses. Six badges registered over 1000 roentgens. Badge locations on NEVADA, on the other hand, were generally deep within the ship and generally protected by heavy armor. Doses recorded on NEVADA were thus low, the highest being 440 roentgens for a location on the third deck. First appearances indicate that PENNSYLVANIA sustained the higher total dose but close analysis indicates quite the reverse. There are practically no comparable badge locations on the two vessels. Only one roughly comparable location was found. A badge in D-430-T on NEVADA registered 4.9 roentgens while a badge in A-427-M on PENNSYLVANIA registered but 0.23 roentgens. Fortunately, NEW YORK, the third battleship, had several badge locations comparable to those on PENNSYLVANIA

and several in locations comparable to NEVADA. Moreover, the total dose on NEW YORK is apparently midway between the other two. PENNSYLVANIA is used as the quantitative check point, the estimated total dose being 3500 roentgens as determined by comparison with close neighbors, particularly CATRON. Based on a study of the data in Figure 21-A, the following total doses are estimated.

		ACCURACY EVALUATION
PENNSYLVANIA	3500 R	B
NEW YORK	4000 R	B
NEVADA	4500 R	B

49. Cruisers. PENSACOLA had two unshielded badges which registered 6700 roentgens and 10,000 roentgens respectively. Since the deposit dose on this vessel was calculated to be 6700 and she was located so as to receive a large surge radiation dose, the latter value is probably more nearly correct. In the absence of other data, a value of 10,000 roentgens, accuracy evaluation B, is estimated. SALT LAKE CITY also had two unshielded badges, registering 1600 and 2400 roentgens. These badges, unfortunately, were located under the turret overhangs and thus derived considerable shielding apparently. This estimate is supported by high internal readings: Pilot House 1700; Windless Room, 1400; Emergency Radio Room, 1500. The pilot house on PENSACOLA had readings of only about 3000 roentgens. After study of badge data in Figure 21-C and comparison with neighboring targets, an estimate of 3250 roentgens total dose, accuracy evaluation C, was made for the SALT LAKE CITY.

50. Submarines. The data on SKATE and PARCHE is difficult to assess quantitatively. The badge reading of 6800, recorded in SKATE's officer's country, appears to be erroneous. The best probable reading appears to

be that in the forward escape trunk, 2800 roentgens. Elementary considerations of the shielding involved make a total dose estimate of 5000 roentgens reasonable. The accuracy evaluation is judged to be D. The PARCHE readings are only about one-seventh of those on SKATE. However, PARCHE had increased shielding from superstructure which SKATE had lost in Test ABLE. Consideration of the data and the deposit doses received, make an estimate of 2000 roentgens total dose appear reasonable. The accuracy evaluation is D.

51. No estimates were made on the following vessels because of lack of data or poor opportunities for comparison:

INDEPENDENCE (CVL22)
PRINZ EUGEN (IX300)
YOG 32
ARDC 13

It is proposed to estimate these values from contours based on the remainder of the array. Figure 27 summarizes the total dose estimates. Figure 28 depicts contours of total dose based on the values in Figure 27. Based on the contours of Figure 28, values of total dose for the above vessels are:

INDEPENDENCE	4000 R
PRINZ EUGEN	2800 R
YOG 83	6000 R
ARDC 13	4000 R

52. A rough check upon the general validity of the contours of total and deposit dose, and the estimates which they represent, can be made by plotting the contours of surge radiations. The surge radiation dose can be obtained for each target ship by subtracting the estimated deposit

dose from the estimated total dose. If both dose estimates are consistent throughout the array, the contours dictated by the array of surge radiation values should exhibit certain characteristics. In general, the contours should be fair, with no inconsistent values and the contours should be oriented so as to agree with the orientation of the base surge. Contours of surge radiation derived by subtracting the deposit dose data of Figure 15 from the total dose data of Figure 28 is plotted in Figure 29. It will be noted that the surge radiation contours are oriented with the wind direction. In general, individual values are consistent with the contours. Two or three exceptions are present. The surge radiations values for MAYRANT and LCT 818 are considerably higher than might be expected. The amount of surge radiation on CRITTENDEN and STACK, however, appear low. No variation is greater than the estimated accuracy. These variations point up the difficulty of deriving firm results from faulty or fragmentary data. No arbitrary adjustments have been made in the total dose or deposit dose data to bring the above vessels into alignment with the surge radiation contours.

53. The contours of surge radiation exhibit a simple single peaked surface of distribution over the array. The maximum is roughly in the center of the array and is estimated to be about 5500 roentgens. The deposit dose in the center of the array was estimated to be 650 roentgens (paragraph 40). Hence, the total dose in the center of the array would be about 6000 roentgens, roughly. This indicates the depth of the hollow in the total dose distribution in the center of the array.

54. Paragraphs 26 through 53 contain the most complete analysis of the gamma radiation hazard from the Test Baker underwater burst which has

been made to date. It is believed to be qualitatively accurate. That is, it is believed that the hypotheses constructed to explain the propagation and the distribution of the gamma radiation hazard are true and that the relative contributions of each of the mechanisms involved (base surge, mushroom fallout, etc.) have been correctly assessed. Further, it is believed that the foregoing analysis, as summarized in Figures 4, 15, 20, 28 and 29, is reasonably accurate in a quantitative sense within the limitations of the basic data. The analysis, of course, applies directly to the Test Baker burst. For design purposes, a more generalized statement of the hazards involved is necessary. The following paragraphs attempt to formulate a reasonable design standard; an average expectancy for gamma radiation hazards from an underwater burst of an atomic bomb.

55. There are a great many variables involved in the phenomenon of an underwater atomic burst. No attempt will be made to predict variations from the Test Baker burst which depend upon certain of these variables. These variables will be held constant and the resulting Test Baker phenomena will be considered to apply in the general case. The variables held constant are the size and efficiency of the bomb, the depth of water in way of the burst, the depth of the burst, the physical conformation of the lagoon bottom and surrounding islands, including the variations of wind, wave, tide and water currents influenced by them, and the temperature and humidity which existed at the time of the Test Baker burst. In other words, the factors directly affecting the propagation of the gamma radiation hazard are considered to be identical with those affecting the Test Baker burst. Factors influencing the distribution of the hazard over the area surrounding the burst are generalized in the following paragraphs.

[redacted]

56. Wind Velocity. The wind velocity (six knots) which was present during Test Baker is not representative of the mean wind velocity to be expected. As discussed in paragraph 9, a design wind velocity of 15 knots will be assumed. Figure 6 describes the motion of the base surge at design wind velocity. It will be necessary to alter the contours of deposit, surge and total dose distribution to account for the increased wind velocity.

57. Deposit Dose Distribution. The actual distribution of deposit dose from Test Baker is shown in Figure 15. As discussed in paragraphs 37 to 40 and as shown in Figure 20, the irregular series of deposit dose maxima are the result of early fallouts of radioactive "rain" from the mushroom head. Ideally, this fallout should form a ring or circular maximum entirely around the center of the burst. The average expectancy or mean value of deposit dose in way of the fallout ring was determined in paragraph 39 to be about 4000 roentgens. This value will be used in constructing contours of deposit dose for design purposes. It will be noted that the deposited fission products are delivered by two mechanisms; primarily by the mushroom fallout and, to a lesser extent, by condensation of the base surge. In addition, some of the fallout material, upon striking the surface of the water, mixes with air and drifts downwind, reinforcing the contaminating influence of the base surge. As discussed in paragraph 40, the deposit dose in the center of the array was found to be 650 roentgens. This dose was due to condensation from the base surge and water column, reinforced by some contamination from the part of the fallout ring directly upwind. As a rough approximation, the deposit dose contributed by the base surge in this region may be considered to be about 500 roentgens. Thus, in way of the fallout ring maximum of 4000 roentgens, 3500 roentgens

may be the result of the average fallout and 500 roentgens due to the base surge deposit. Figure 30 shows contours of mean deposit dose distribution around a Baker-type detonation under the action of a 15 knot wind as indicated. The base surge and mushroom are both considered subject to the same wind in velocity and direction. The wind is coming from the top of the figure to conform with the wind direction in Figure 6. It was noted (paragraph 37) that the center of the fallout ring at Test Baker was displaced downwind a distance equal to the free movement before the existing wind during a time interval of one minute. The center of the fallout ring in Figure 30 is located 500 yards downwind of the center of the burst. This is the distance traveled in one minute under the action of a 15 knot wind. The mean diameter of the fallout ring remains 1600 yards as in Test Baker. To conform with the assumptions used in plotting Figure 6, the effective distance of base surge upwind is considered to remain the same regardless of the increased wind velocity. This assumption is probably somewhat pessimistic. The rate of fall-off of the deposit upwind, as indicated by the contours has been flattened in view of the movement of the fallout ring further downwind because of the increased wind velocity. The crosswind distribution of deposit dose is unaffected by the increased wind velocity. Downwind, the extent of the various deposit dose contours has been determined by assuming that the deposit beyond three thousand yards is controlled by the base surge movement entirely. For instance, the actual extent of the 500 roentgen contour downwind in Figure 15 is 3200 yards. This corresponds with the position of the face of the base surge at burst plus four minutes (Figure 5). Figure 6 indicates that at burst plus four minutes, the base surge would reach 3500 yards downwind under the influence of a 15 knot wind. Therefore the 500 roentgen contour is extended to 3500 yards downwind in Figure 30 to indicate the wind effect. Other contour locations have been determined similarly.

58. Surge Radiation Dose Distribution. The actual surge radiation dose distribution which occurred in Test Baker is plotted in Figure 29. It is believed that this distribution would remain substantially the same under a 15 knot wind because of the following reasons:

(a) Most of the surge radiation occurs during the first few minutes after the burst because of the rapid decay of the intensity of gamma radiation. To support this, it will be noted that the 500 roentgen contour in Figure 29 is closer to the center of the burst at any bearing than is the face of the base surge at burst plus two minutes (Figure 3). Comparison of Figures 3 and 6 shows that the growth of the base surge up to burst plus three minutes is affected only slightly by an increase in wind velocity from six to 15 knots. Consequently, the contours of 500 roentgens and greater will remain substantially the same.

(b) The 100 roentgen contour conforms to the outline of the base surge envelope except in its extent downwind. It is considered that the increased rate of movement of the base surge downwind after three minutes because of the higher wind velocity will be more than offset by the tendency of the base surge to lift from the surface at an earlier time. Consequently, no change is warranted in the 100 roentgen contour. Figure 31 is therefore similar to Figure 29 but with complete symmetry about the wind axis restored and the wind axis shifted to conform with Figure 6 and 30.

59. Total Dose Distribution. The total dose distribution for design purposes is obtained by summing the effects of the deposit dose and the surge radiation dose (as plotted in Figures 30 and 31) over the affected area. The resulting contours of total gamma radiation dose are plotted in Figure 32. The shape of the inner contours is of some interest, though of little practical value. In a no-wind condition, the total dose curve would exhibit the character of an even and increasingly rapid rise in all bearings to an annular or "ring" maximum with an approximate mean diameter of 1600 yards. Inside the ring maximum a shallow "crater" would exist in the surface of total dose distribution. When a wind is blowing, the deposit dose distribution tends to move downwind while the surge radiation dose distribution is very little affected. Theoretically, a very high wind (say 120 knots) would cause complete dissociation of the two effects, the deposit from the mushroom falling in an otherwise unaffected area downwind. In Figure 32, the 15 knot wind has caused the shallow crater to become nearly a plateau of about 6000 roentgens downwind of a single peak of 9000 roentgens. The remnants of the no-wind ring maximum are

[redacted]

still represented by a dotted contour in the neighborhood of 7000 roentgens. For practical design considerations, the contours within the 6000 roentgen contour can be ignored and an even growth to a 9000 single maximum at the center of the target area assumed.

60. Figures 6, 30, 31 and 32 give the design data necessary for consideration of the gamma radiation hazard resulting from a Baker-type atomic bomb detonation under mean conditions. The data represents the distribution of gamma radiation dose to infinity in time over the target area. For problems involving vessels underway which are subjected to the hazard for only a short period of time, the time-intensity and space-intensity characteristics of the gamma radiation must be known. These characteristics will be the subject of a separate study.

 [redacted]

Figure 16. Photograph of BAKER array from Amen Isl[illegible] 30 seconds. Verticals have been pass[illegible] through location of BRULE, PENSACOLA and YOG 83. BRULE is in contact with the base surge while PENSACOLA has already disappeared. Fallout over these vessels is indicated. Note earliest fallout falling beyond PENSACOLA in southern sector of array. This view is from AF 593.

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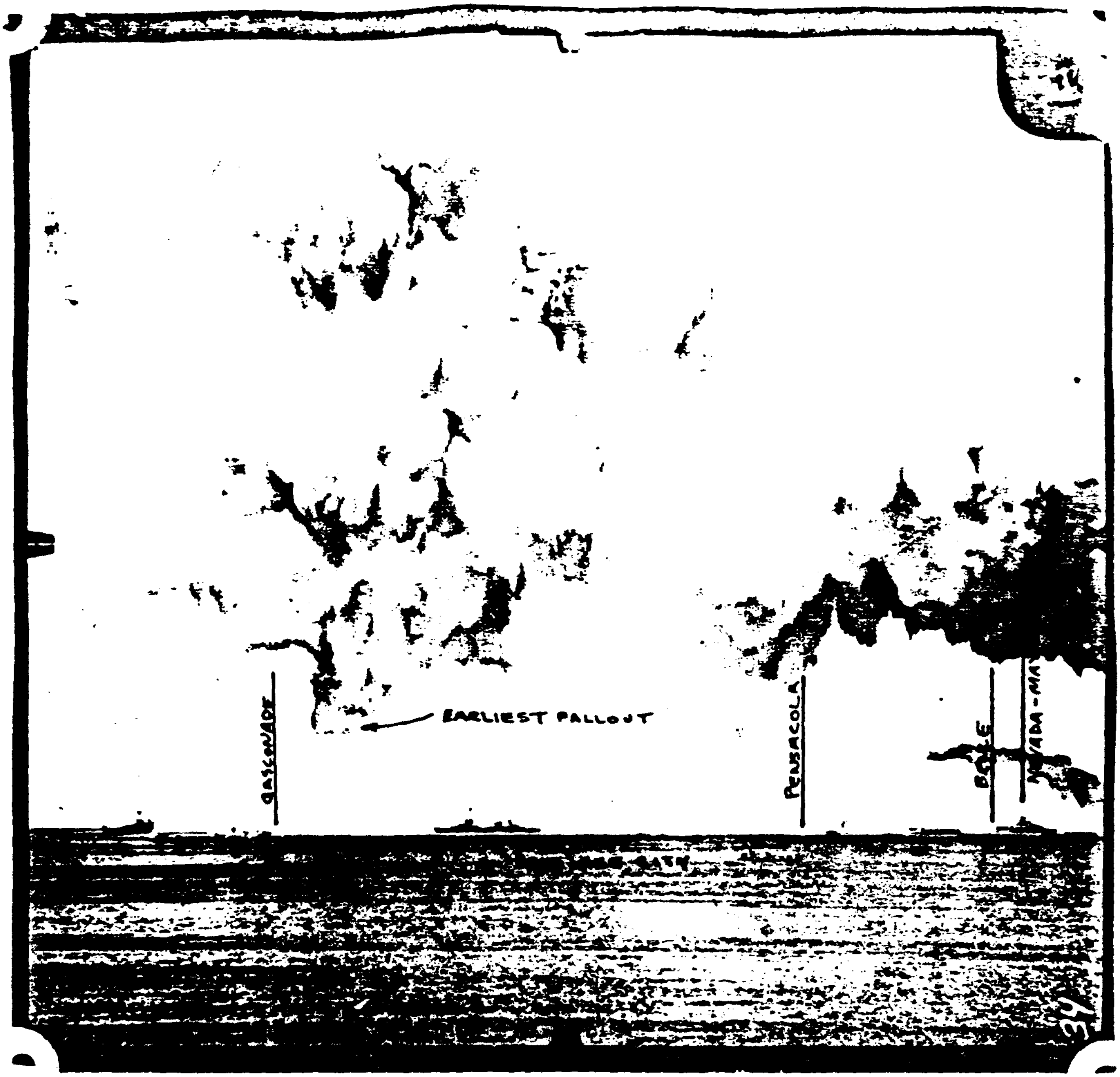

Figure 17. Photograph of BAKER array from Bikini Island (Tower [illegible]) at burst plus 30 seconds. Verticals have been passed through key target vessels. Note earliest fallout falling beyond GASCONADE into empty space in array between PENNSYLVANIA and [illegible]. Also note "hole" in fallout over SALT LAKE CITY. This view is from AF 647.

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Figure 18. Photograph of BAKER array from Enyu Island at burst plus 30 seconds. Verticals have been passed through key target vessels. PENSACOLA is beyond location of earliest fallout. Note "hole" in fallout in neighborhood of NEW YORK. This view is from AF 878.

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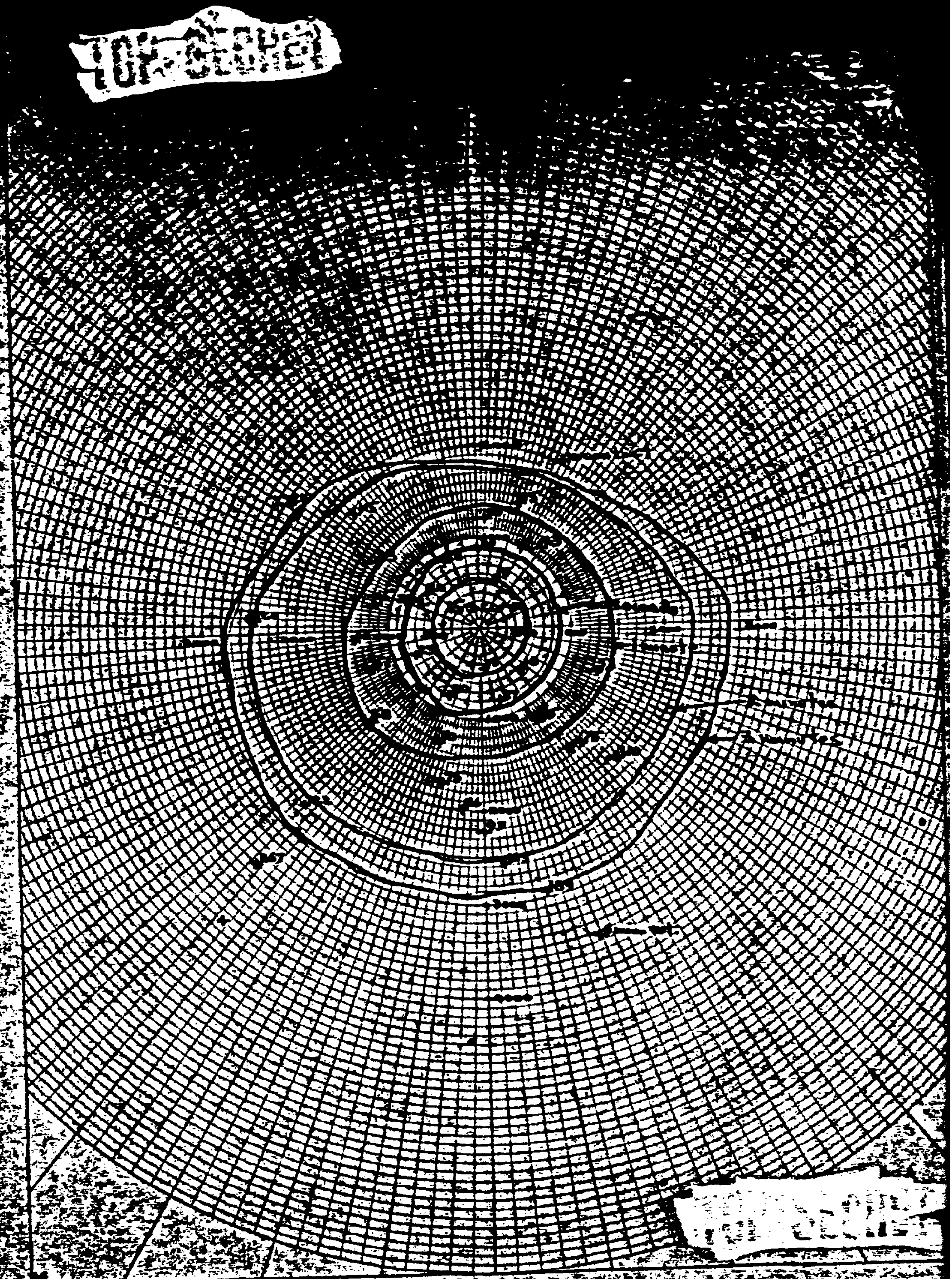
Figure 19. Photograph of BAKER array from Amoen Island at burst plus 30 seconds. Verticals have been passed through key target vessels. Fallout between NEVADA and MAYRANT has just begun to leave mushroom while that over YOG 83 and BRULE is well advanced. Earliest fallout may be seen at extreme right. This view is from AF 592.

SHIP	DISTANCE FROM BURST TO NEAREST POINT OF SHIP	TIME, DETONATION TO CONTACT WITH AUTHORITY: AF 529	AF 594	AF 647	AF 578	AF 638	AF 673	AF 637	UNIDENT. AERIAL	AF 592	AF 629	CONSENSUS
FALLON	465								13			13 seconds
GASCONADE	575				15	15	15		15			15 seconds
HUGHES	630			20								20 seconds
LST 133	630			20								20 seconds
PENSACOLA	640								16			16 seconds
NAGATO	745		21	25								23 seconds
LCT 816	800			30								30 seconds
NEW YORK	800			28	27			28				28 seconds
MAYRANT	800	20	21						16			20 seconds
BRULE	855	27										27 seconds
BRISCOE	875				30		29					30 seconds
NEVADA	1030		35	37								36 seconds
PENNSYLVANIA	1100							43				43 seconds
SALT LAKE CITY	1125			45								45 seconds
DAWSON	1175	45										45 seconds
CATRON	1200				48	51		50				50 seconds
ARDC 13	1217		48	54								51 seconds
MUSTIN	1275			63								63 seconds
TRIPPE	1320	50	49									50 seconds
LCT 818	1360			55								55 seconds
INDEPENDENCE	1380				53		53					53 seconds
BRACKEN	1425				75	75						75 seconds
LST 52	1530		58							80		58 seconds
CRITTENDEN	1675	75										75 seconds
WILSON	1760	75										75 seconds
RALPH TALBOT	1815		NO	DATA								
LCI 332	1870		~~NO~~	~~DATA~~							115	115 seconds
STACK	2000	86	86									86 seconds
FILLMORE	2010		NOT	CONTACTED								NO CONTACT
PRINZ EUGEN	2000	96										96 seconds
BARROW	2050	110										110 seconds
RHIND	2040	92	94									93 seconds
BANNER	2490	NO	DATA									
MUGFORD	2600	125										125 seconds
WAINWRIGHT	2950	187										187 seconds
CONYNGHAM	3535	[illegible]										[illegible]
LCT [illegible]	[illegible]			120								120 seconds
[illegible]	[illegible]											124 secs
[illegible]	[illegible]											147 secs
[illegible]	[illegible]											[illegible]
[illegible]	[illegible]										210	210 seconds

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FALCON	465								15			15 seco
GASCONADE	525				15	15	15		15			15 se
HUGHES	630			20								20 seco
LST 133	630			20								20 seco
PENSACOLA	640								16			16 seco
NAGATO	745		27	25								25 seco
LCT 816	800			30								30 seco
NEW YORK	800			[illegible]	27			28				28 seco
MAYRANT	800	20	21						16			20 seco
BRULE	855	27										27 seco
BRISCOE	875				30		29					30 seco
NEVADA	1030		35	37								36 seco
PENNSYLVANIA	1100							43				43 seco
SALT LAKE CITY	1125			45								45 seco
DAWSON	1125	45										45 seco
CATRON	1200				48	51		50				50 seco
ARDC-13	1217		48	54								51 seco
MUSTIN	1275			63								63 seco
TRIPPE	1320	50	49									50 seco
LCT 818	1360			55								55 seco
INDEPENDENCE	1380				53		53					53 seco
BRACKEN	1425				75	75						75 seco
LST 52	1530		58							60		58 seco
CRITTENDEN	1675	75										75 seco
WILSON	1760	75										75 seco
RALPH TALBOT	1815		NO	DATA								
LCI 332	1870		~~NO~~	~~DATA~~							115	115 seco
STACK	2000	86	86									86 seco
FILLMORE	2010		NOT	CONTACTED								No cont
PRINZ EUGEN	2000	96										96 seco
BARROW	2050	110										110 seco
RHIND	2040	92	94									93 seco
BANNER	2490	NO	DATA									
MUGFORD	2600	125										125 sec
WAINWRIGHT	2950	189										189 sec
CONYNGHAM	3585	6 min										6 min. e
LCT 874	2420			120								120 sec
LST 661	2653									122		122 s
LST 220	2660									267		267 s
LST [illegible]	[illegible]									—		
LCI 327	2433										210	210 sec

FIGURE 1



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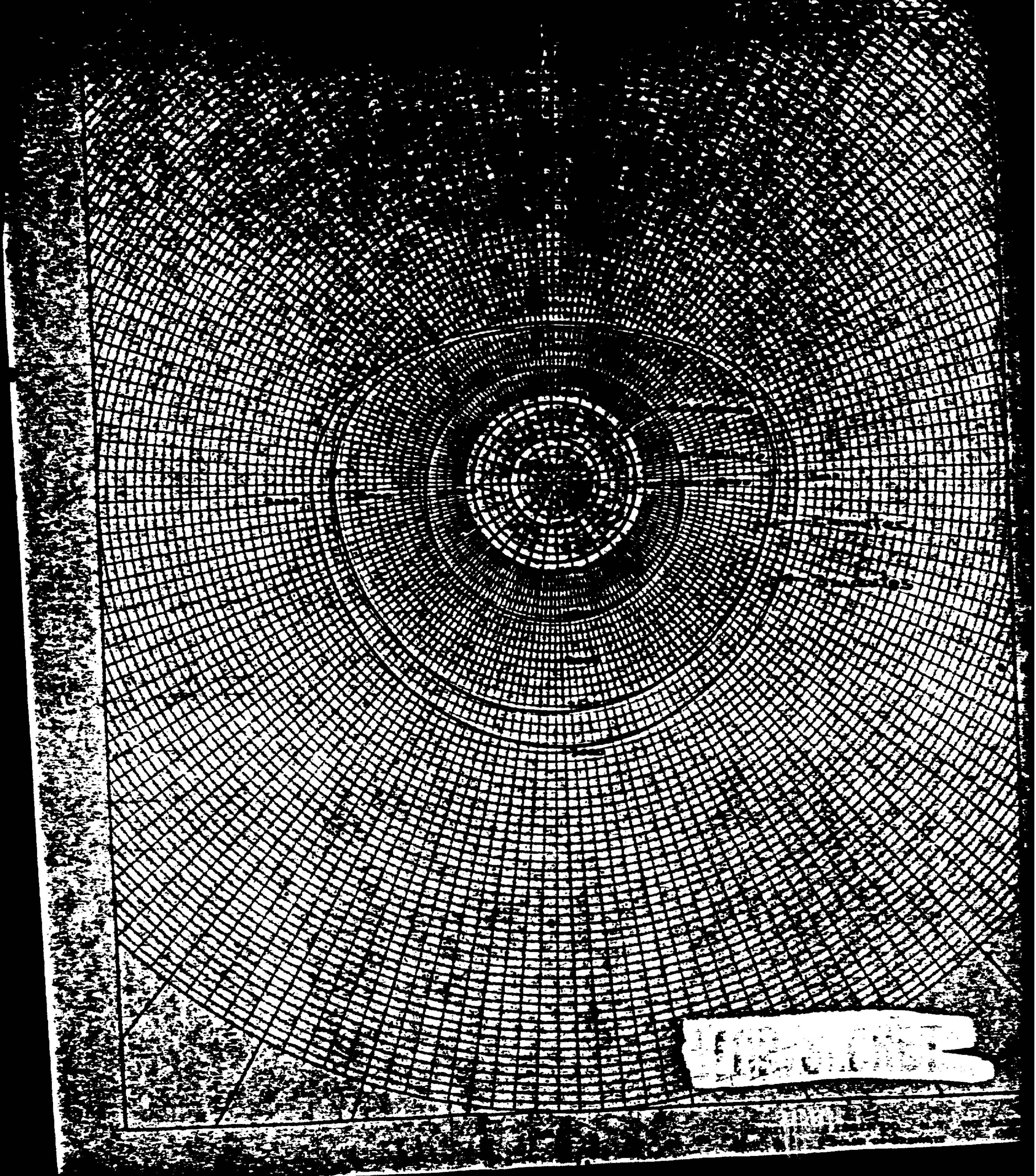

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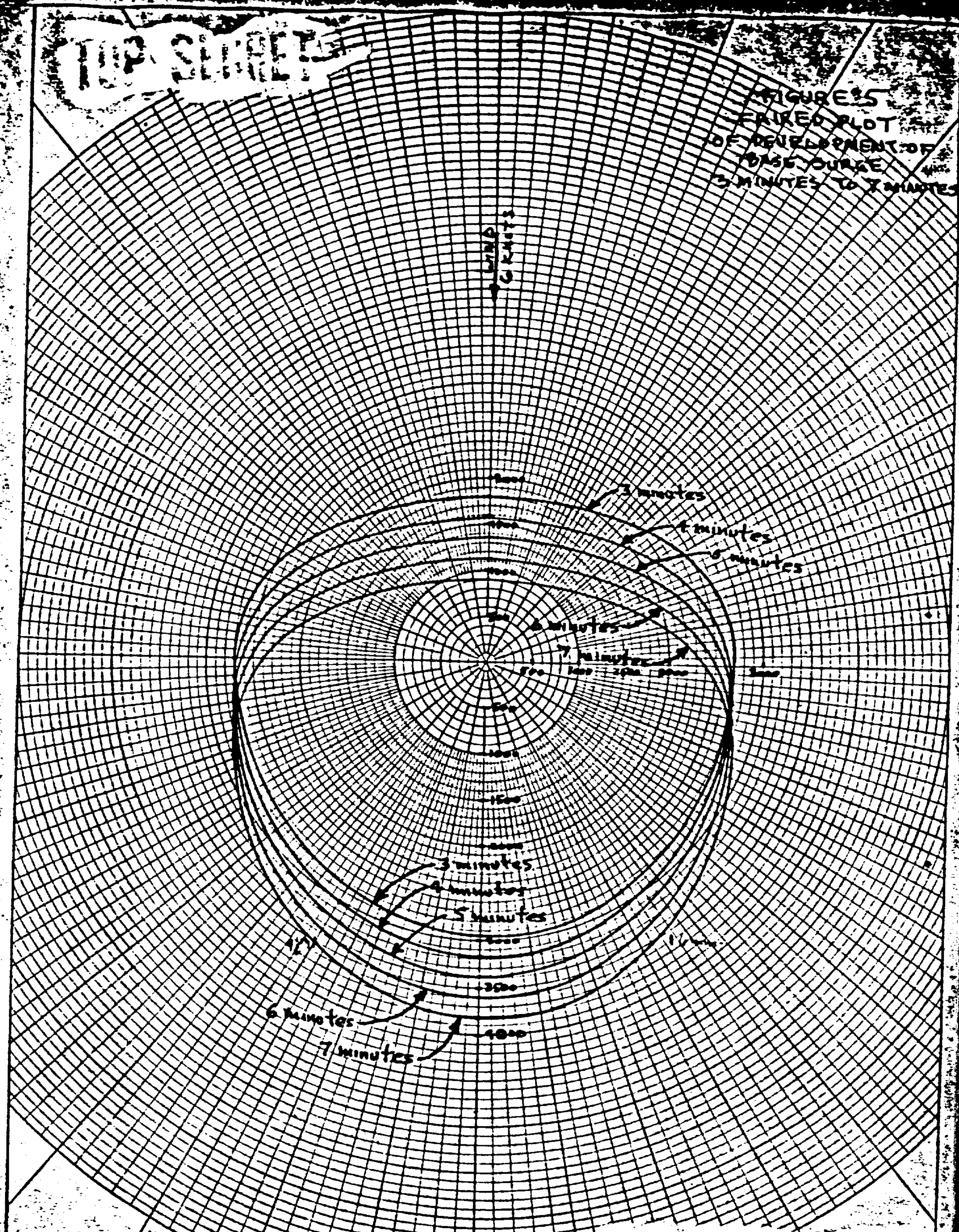

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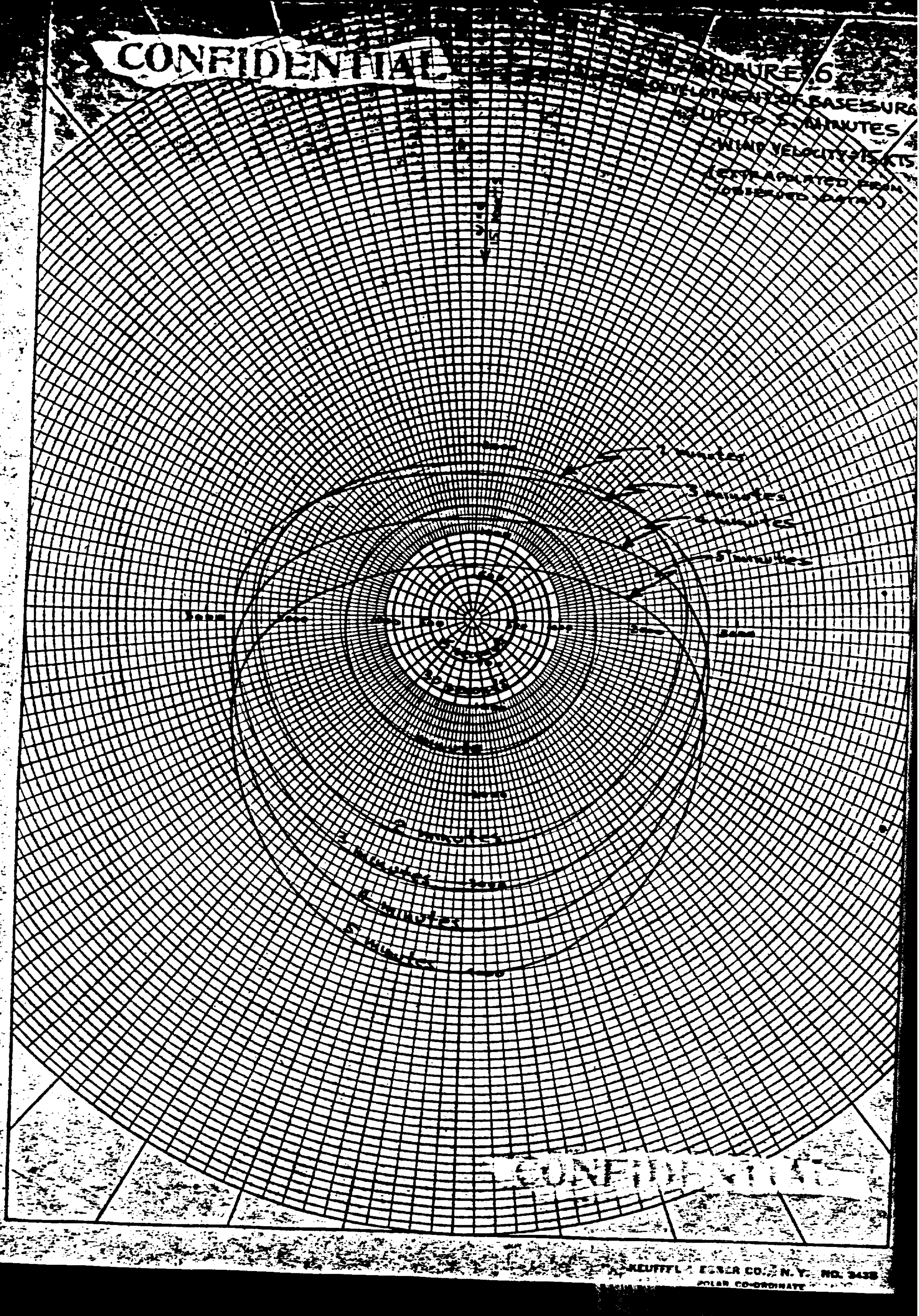

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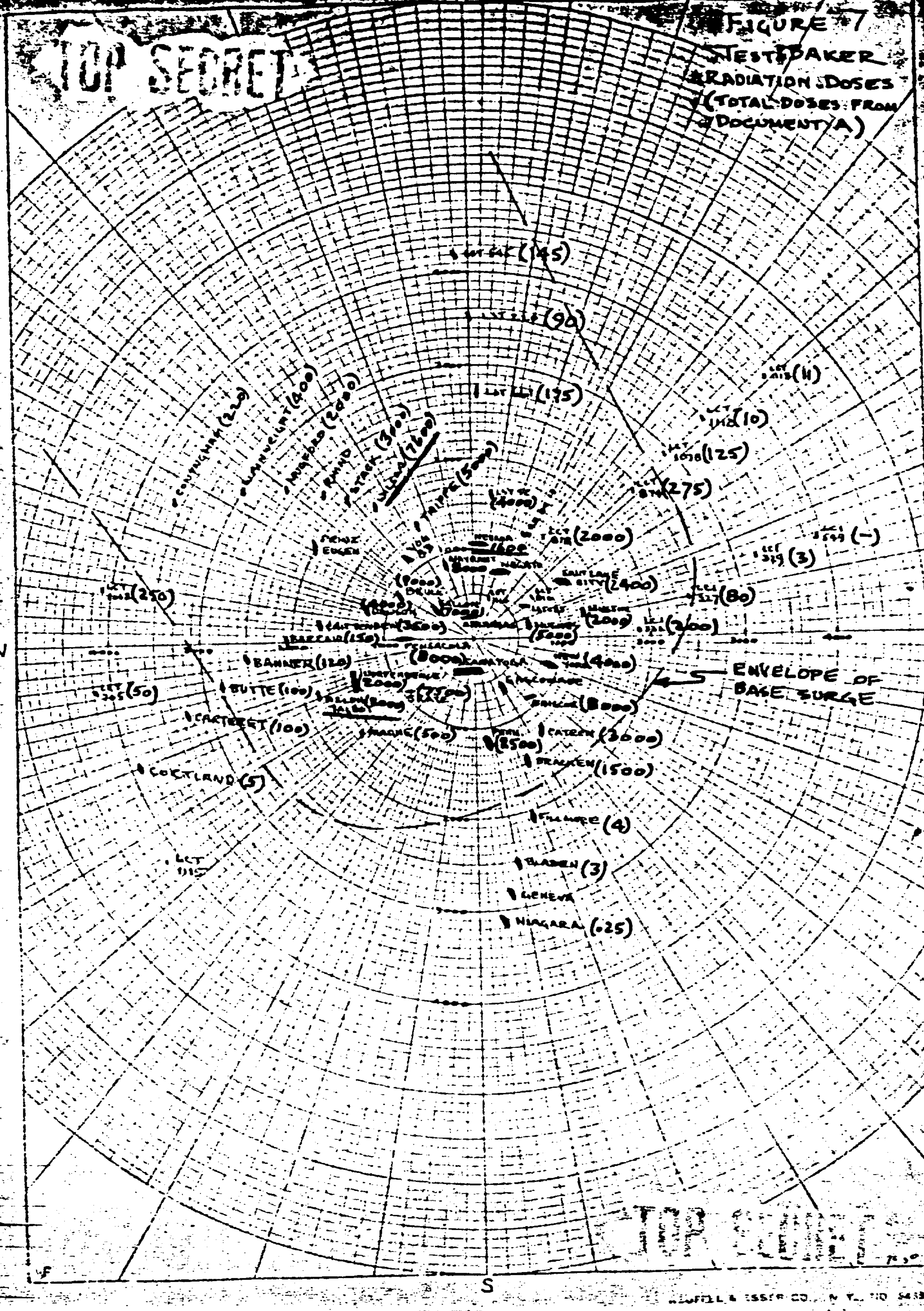
FIGURE 7
TEST BAKER
RADIATION DOSES
(TOTAL DOSES FROM DOCUMENT A)



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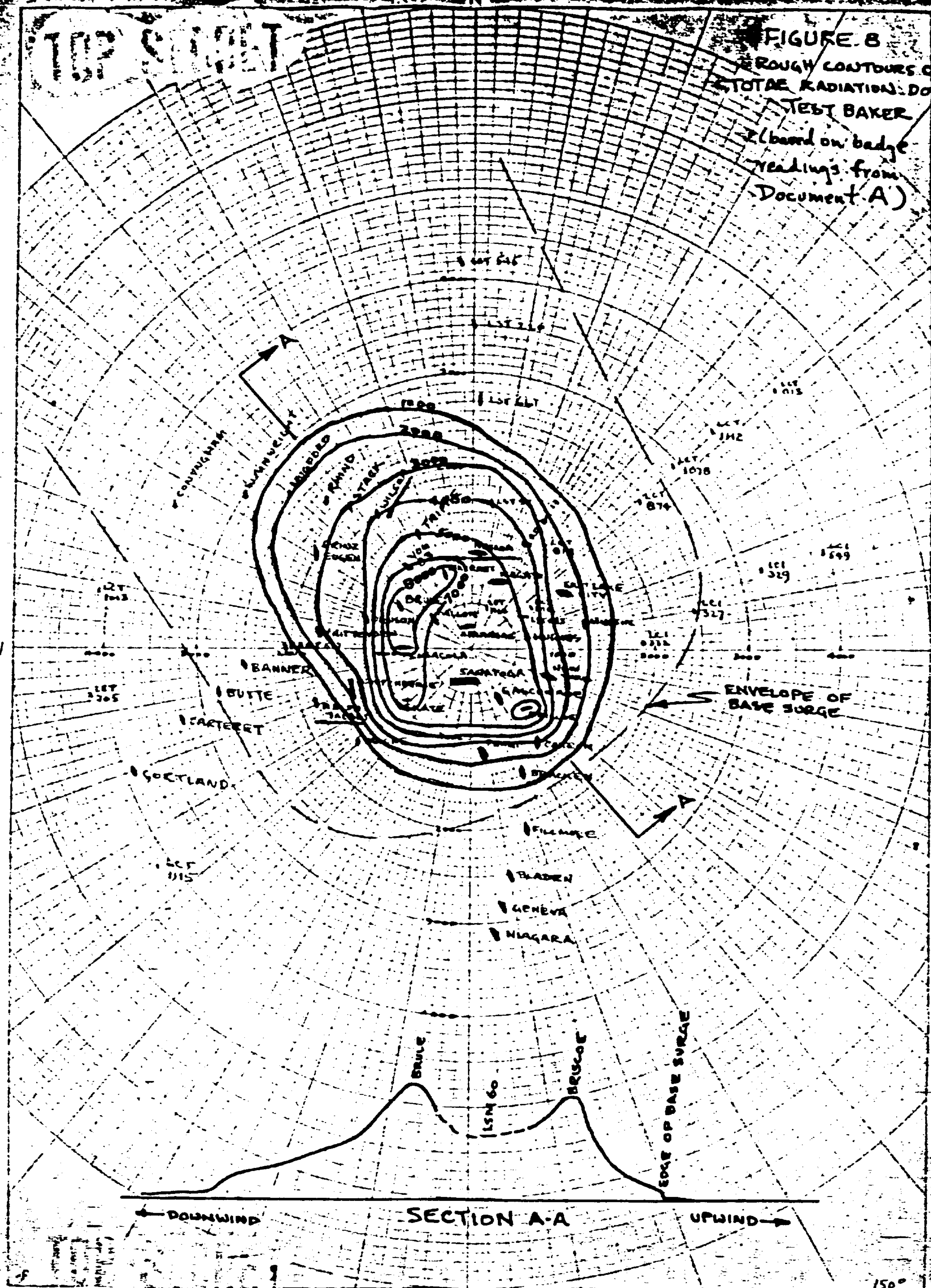

FIGURE 8
ROUGH CONTOURS OF TOTAL RADIATION DOSE
TEST BAKER
(based on badge readings from Document A)

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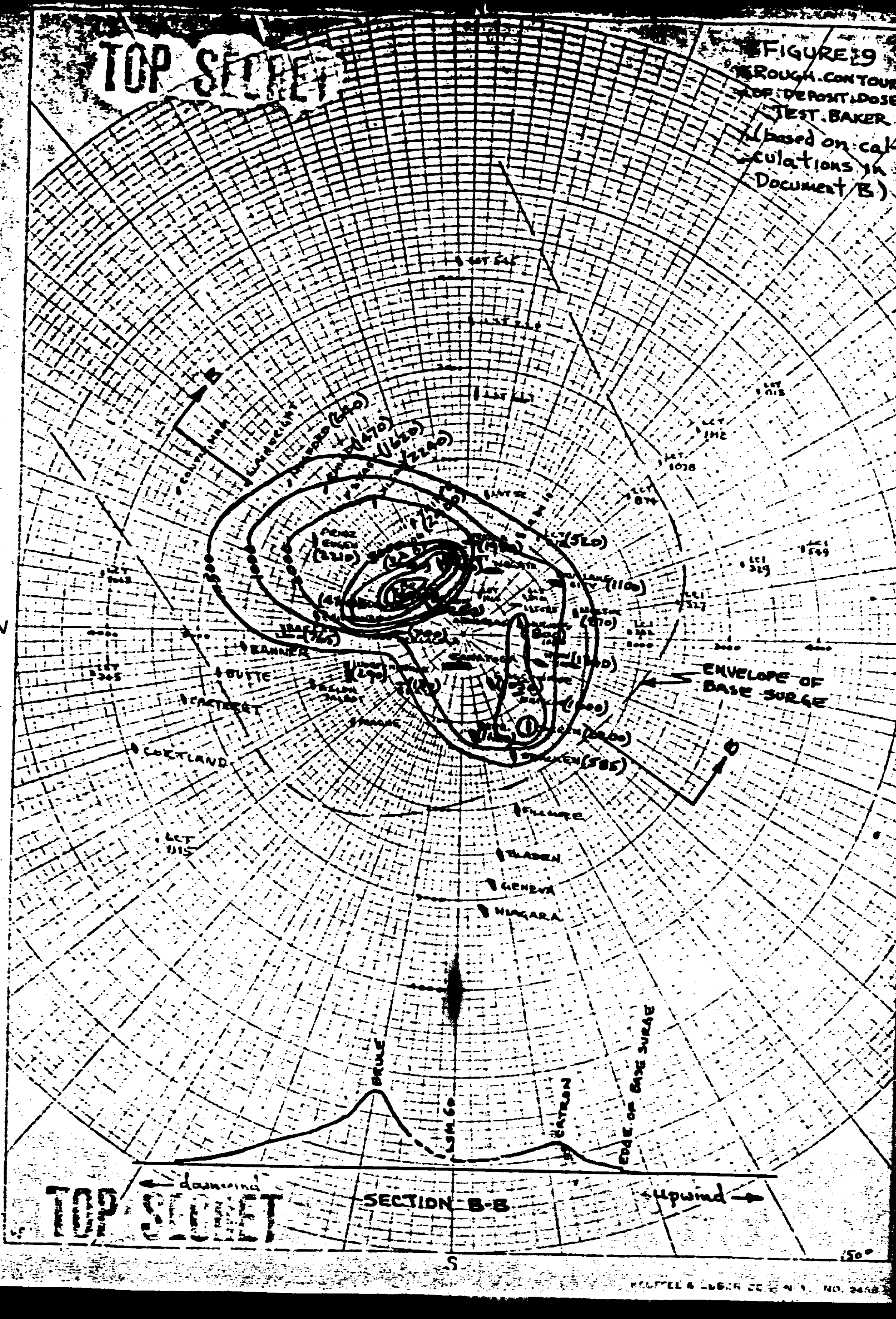
[illegible]

TOP SECRET

FIGURE 9
ROUGH CONTOURS OF DEPOSIT DOSE
TEST BAKER
(based on calculations in Document B.)



TOP SECRET

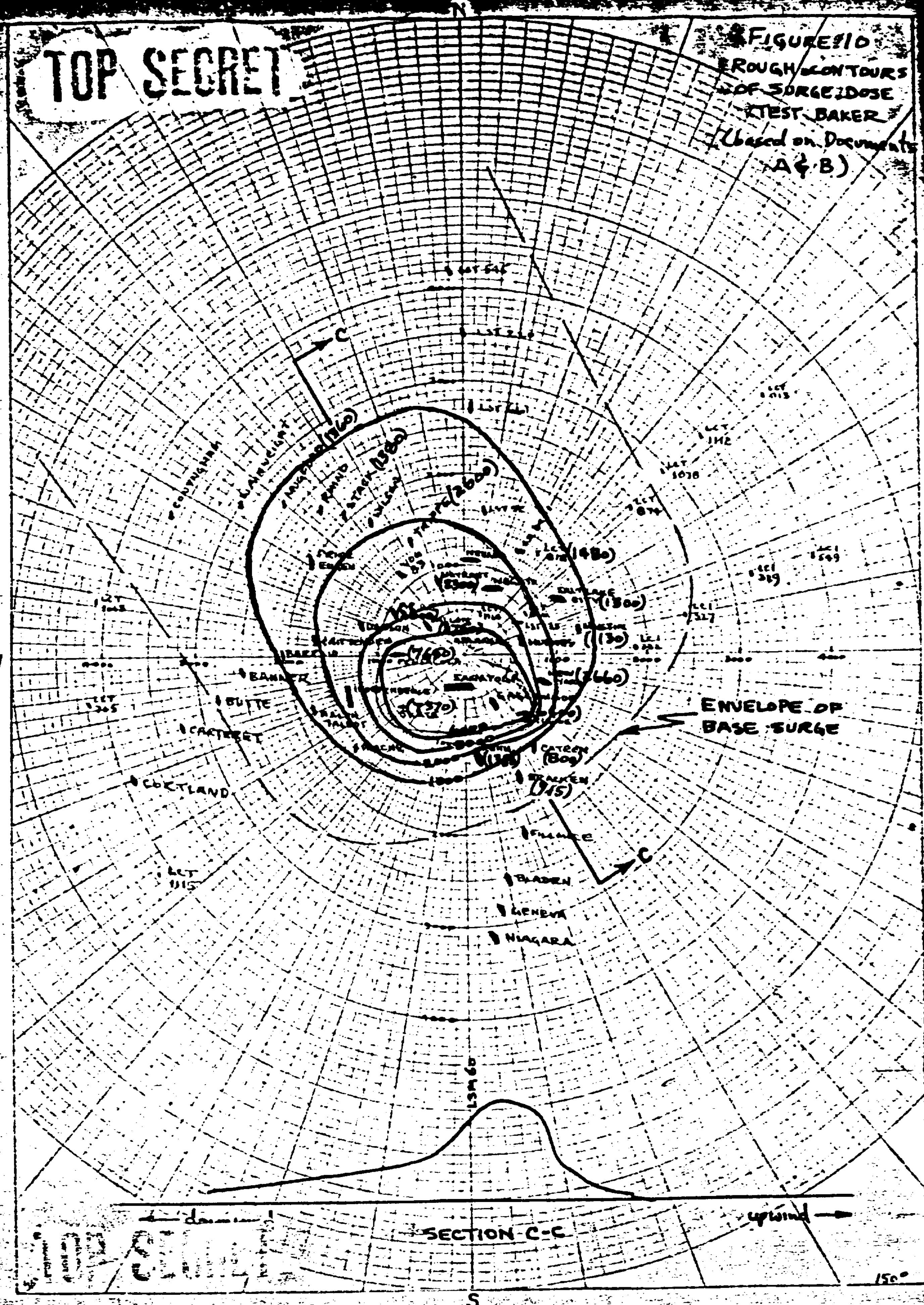
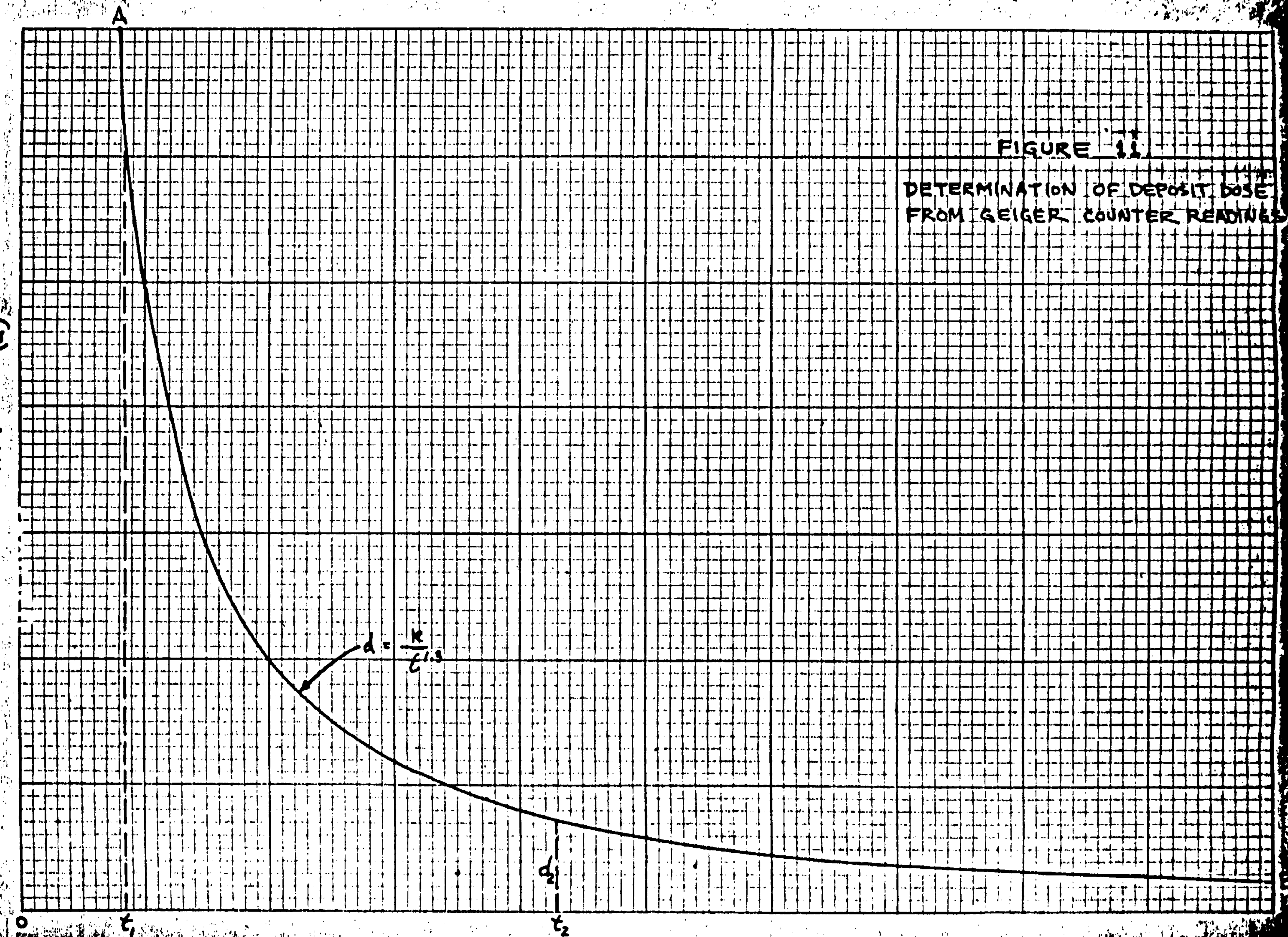

TOP SECRET
FIGURE 10
ROUGH CONTOURS OF SURGE DOSE TEST BAKER
(based on Documents A & B)
N
S
W
E
C
C
ENVELOPE OF BASE SURGE
CORTLAND
BUTTE
BANNER
CARTERET
GENEVA
NIAGARA
BLADEN
SECTION C-C
downwind
upwind
TOP SECRET

FIGURE 11

DETERMINATION OF DEPOSIT DOSE FROM GEIGER COUNTER READINGS



VESSEL	[illegible]	[illegible] (DAYS)	[illegible]	[illegible] DOSE	REMARKS	ESTIMATED DEPOSIT DOSE (ROENTGENS)	ACCURACY EVALUATION
NEW YORK (BB 34)	28	3	7.2	4120	NO DECONTAMINATION		
		13	1.75	1820	PORTION OF UNCOATED DK		
		12	2.5	2345	AVE. TOPSIDE; 5 WASHINGS	1900	B
		16	1.3	1780	SOURCE: AFSWP		
		7	4.0	1868	FROM DETAIL REPORTS, I FORM		
NEVADA (BB 36)	36	12	3.0	2610	SEVERAL WASHINGS		
		14	1.5	1600	DOUBTFUL READING		
		15	2.0	2328	FR. APPENDIX VII	2500	A
		21	1.5	2700	SAME SOURCE DETAIL READINGS SUPPORT 2500 R AS AVERAGE		
PENNSYLVANIA (BB 38)	43	12	3.0	2480	TOPSIDE AVE. SEV. WASHES; DETAIL READING SUPPORT.		
		14	1.5	1515	FR. IBDR, PAGE 13		
		19	1.5	2250	FROM APPENDIX VII	2500	B
					SHIP WASHED ON B+4 AND SUBSEQUENT. NO PRIOR READINGS		
INDEPENDENCE (CVL 22)	53	14	3.0	2840	NO DECONTAMINATION		
		15	2.5	2590	" "		
		17	3.0	3660	" "	3000	B
PENSACOLA (CA 24)	16	7	12.0	6700	NO DECONTAMINATION		
		8	10.0	6550	SOME DECONTAM. (1 WASH)	6700	A
		11	6.0	5970			
		14	4.5	6110			
		19	2.5	5060	CONSIDERABLE DECONTAM.		
SALT LAKE CITY (CA 25)	45	7.5	3.0	1328	NO DECONTAMINATION		
		12	2.5	2035	AVE. TOPSIDE, SOME DECONTAM.		
		14	2.0	1990	" "	1750	B
		20	0.8	1260	" "		
PRINZ EUGEN (IX 300)	96	7	5.5	1770	VESSEL WASHED ON		
		9	4.0	1790	B+8	1750	A
					NO OTHER DATA		
SKATE (SS 305)	30	7	4.5	2060	WASHED B+5 & B+6		
		9	3.0	1900	INEFFECTUAL DECONTAM.	2000	B
		11	2.0	1640	FOAMED AND WASHED		
		15	1.2	1476	SOME DECONTAMINATION		
PARCHE (SS 384)	100	6	5.2	1350	NO DECONTAMINATION		
		7	5.1	1630	" "	1500	A
		8	4.1	1550	" "		
		9	3.5	1590	" "		

FIGURE 12-[illegible]

[illegible] (APA [illegible])	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]500	D
[illegible] (APA [illegible])	110	[illegible]	[illegible]	[illegible]	[illegible]		
		6	[illegible]	[illegible]	[illegible]	1050	A
		6	2	2757			
BRAXTEN (APA 66)	75	2	110	2275	FORMERLY ONLY PARTIAL [illegible]		
		[illegible]	110	1520			
		7	7.0	1075	AVG. ACTOR 1 [illegible]	1100	A
		9	7.7	1016	[illegible]		
		2	7.0	1055	[illegible]		
ARMOOR (APA 65)	50	4	20.0	4200	[illegible]		
		7	25	2060	[illegible] 2 MACHES		
						3000	C
		8	25	1560	AVE. [illegible]		
		11	0.7	2400			
		13	1.5	6540	[illegible] APPENDIX XII		
BRULE (APA 68)	157	12	5.0	6770	[illegible] APPENDIX XII		
		12	2.0	8120	[illegible] IBDR		
		15	7.0	6340	APPENDIX XII		
		16	4.0	6100	APPENDIX XII		
		16	8.5	9500	[illegible]	5100	B
		20	7.0	5490	APPENDIX XII		
BUTTE (APA 68)	206 (est)	9	1.0	359	IBT #2 REPORT		
		9	0.8	288	IBDR		
		12	0.8	208	DETAIL READINGS		
						300	B
		13	0.3	377	IBDR		
		13	0.2	257	APPENDIX XII		
		12	0.2	254	IBDR		
		12	0.6	380	APPENDIX XII		
CARTERET (APA 70)	300 (est)	5	1.0	108			
					ALL READINGS CHECK		
	(est)	7	0.4	95			
	[illegible] BY [illegible]	14	0.2	112		100	A
CATRON (APA 71)	50	3	16.0	1550	[illegible] IBDR, [illegible] 21		
		4	15.0	2840	[illegible] IBDR		
		6	7.5	1425	AVE 21 [illegible] 2 MACH	2500	B
					DETAIL READINGS ERROR [illegible]		
[illegible] (APA 72)	75	13	2.0	5313	[illegible] APPENDIX XII		
		14	6.0	3420	[illegible] IBDR		
		15	1.5	3730	[illegible] APPENDIX XII	2750	[illegible]
		17	1.5	1025	[illegible] APPENDIX XII		

FIGURE 12-[illegible]

VESSEL	t_1 (seconds)	t_2 (days)	I (roentgens per hr)	D (deposit dose, roentgens)	REMARKS	ESTIMATED DEPOSIT DOSE (ROENTGENS)	ACCURACY EVALUATION
DAWSON (APA 79)	45	16	8.0	9400			
		19	2.0	3000	VERY LITTLE DATA.		
					READINGS ON 15 DEC 1946 INDICATE DAWSON HAD ABOUT 10% LESS THAN FALLON (5000)	4500	D
FALLON (APA 81)	13	7	4.0	4620	fr. APPENDIX VII		
		20	10	23,000	fr. APPENDIX VII - doubtful		
		132	0.3	8000	LONG-RANGE READING, NOT RELIABLE. 2nd DAY VALUE CONSIDERED ONLY WORTH WHILE READING	5000	D
GASCONADE (APA 85)	15	5	17.0	6150	fr. IBDR (1 WASH)		
		5	13.0	5430	detail readings		
		9	6.0	4680		5000	B
					SOME DECONTAMINATION		
		12	3.5	3960	"		
		14	2.7	3730	"		
		15	2.2	3330	"		
CONYNGHAM (DD 371)	360 (est.)	4	1.0	105	IBDR, page 15		
		6	0.4	72	1 WASH } from detail readings		
		8	0.3	78	1 WASH }	100	A
MUGFORD (DD 389)	125	5	7.0	1340	DETAILED STUDY OF EXTENSIVE READINGS		
		7	5.0	1490	DURING DECONTAMINATION INDICATE THESE VALUES	1500	A
		9	4.0	1645	ARE MOST REPRESENTATIVE		
RALPH TALBOT (DD 390)	80 (est.)	9	3.0	1415	NO DECONTAMINATION		
		14	1.5	1260	1 WASH	1400	B
		16	1.0	1000	AFTER WASHING		
MAYRANT (DD 402)	20	7	4.0	2060	APPENDIX VII		
		14	2.0	2540	APPENDIX VII		
		14	4.0	5980	IBDR (bar reading?)	2500	B
		15	2.0	2775	IBDR		
		18	1.5	2635	APPENDIX VII		
TRIPPE (DD 403)	50	12	5.5	4300	IBDR		
		13	4.0	3510	APPENDIX VII & IBDR	3000	C
		15	2.0	2010	APPENDIX VII		
		16	2.5	2865	" (NO INFO ON DECONTAM)		
		18	2.0	2670	AFSWP		
RHIND (DD 404)	93	9	4.0	1800	1 WASH		
		14	2.0	1605	WASHED TWICE	1800	B
		15	1.8	1575	SHIPBD DECONTAM.		
		16	1.5	1425	" "		
		19	1.0	1190	" "		

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FIGURE 12-C

VESSEL	t_1 (SECONDS)	t_2 (DAYS)	I_2 (ROENTGENS PER DAY)	D (INTEGRAL DOSE IN ROENTGENS)	REMARKS	ESTIMATED DEPOSIT DOSE (ROENTGENS)	ACCURACY EVALUATION
STACK (DD 406)	86	7	9.6	3210	from detail readings		
		9	6.17	2770	before washing.	2750	B
		10	5.4	2860	2 WASHINGS		
		10	4.3	2280	APPENDIX VI		
		13	2.5	1860	3 WASHINGS		
WILSON (DD 408)	75	13	3.0	2315	APPENDIX VII		
		14	3.0	2580	IBDR (no data on decontam.)	2750	B
		15	3.0	2810	APPENDIX VII		
		16	2.5	2530	" "		
HUGHES (DD 410)	20	4	7.7	1920	WASHED & FOAMED		
		9	2.5	1790	2 WASHES & FOAMS	2000	B
		21	1.0	2150	AFSWP		
MUSTIN (DD 413)	63	14	1.5	1350	IBDR, page 17 } after 1		
		14	1.0	900	APPENDIX III } wash		
		16	0.5	537	SHIP DECONTAM.	1000	B
		20	0.3	430	" "		
WAINWRIGHT (DD 419)	189	4	2.5	317			
		7	1.0	262	ONE WASH	300	A
		9	1.0	315			
LST 52	58	14	7.0	6440	NOTE: HEAVY RUST ON DECK		
		18	7.0	8950		6000	B
		19	4.0	5500			
LST 133	20	14	2.5	3160	from detail readings		
		14	2.0	2515	APPENDIX VII	3000	B
		19	1.5	2830	APPENDIX VII		
LST 220	350 (26T)	3	3.0	217	from detail readings		
		13	0.5	244	APPENDIX VII		
		18	0.5	373	"	300	B
		19	0.4	322	"		
LST 545	(540) (est.)	7	0.6	115			
		14	0.4	190		150	B
		3	2.0	127			

FIGURE 12-D

VESSEL	t_1 (SECONDS)	t_2 (DAYS)	I_{t_2} (ROENTGENS PER DAY)	D (INTEGRATED DOSE) (ROENTGENS)	REMARKS	ESTIMATED DEPOSIT DOSE (ROENTGENS)	ACCURACY EVALUATION
LST 661	122	14	7.0	5160	from detail readings		
		15	4.0	3120	APPENDIX III	4000	C
		19	4.0	4260	APPENDIX III		
LCI 327	210	3	2.5	250	from detail readings	250	D
LCI 332	115	4	3.0	450	APPENDIX III		
		18	0.6	674	"	500	B
		19	0.3	361	"		
LCT 705	420 (est.)	4	0.25	25			
		8	0.07	17.5		25	C
LCT 816	30	19	2.0	3090	only data but agrees WITH LST133 which was close.	3000	D
LCT 818	55	3	5.0	630			
		4	3.0	552		600	B
		18	1.5	1950	? from APPENDIX III		
		19	0.4	558	APPENDIX III		
LCT 874	120	4	4.0	580			
		6	2.0	492	from detail readings	500	B
		18	0.1	97	? APPENDIX III		
LCT 1013	420 (est.)	4	0.6	60			
		8	0.3	75		75	B
LCT 1078	240 (est.)	4	0.4	107			
		6	0.4	80		100	B
		17	0.1	78			

FIGURE 12-E

VESSEL	[illegible]	[illegible]	[illegible]	[illegible]	REMARKS	ESTIMATED DEPOSIT 1st DOSE (ROENTGENS)	ACCURACY EVALUATI…
ARDC 13	51	18	7.0	13240	only data available		
						3250	D
YOG 83	45	8	15.0	16830	yarding alongside		
		15	4.0	4352	APPENDIX VII	6000	B
		18	5.0	16900	APPENDIX VII		

NOTE:
VESSELS NOT LISTED HAD A NEGLIGIBLE DEPOSIT.

FIGURE 12-F

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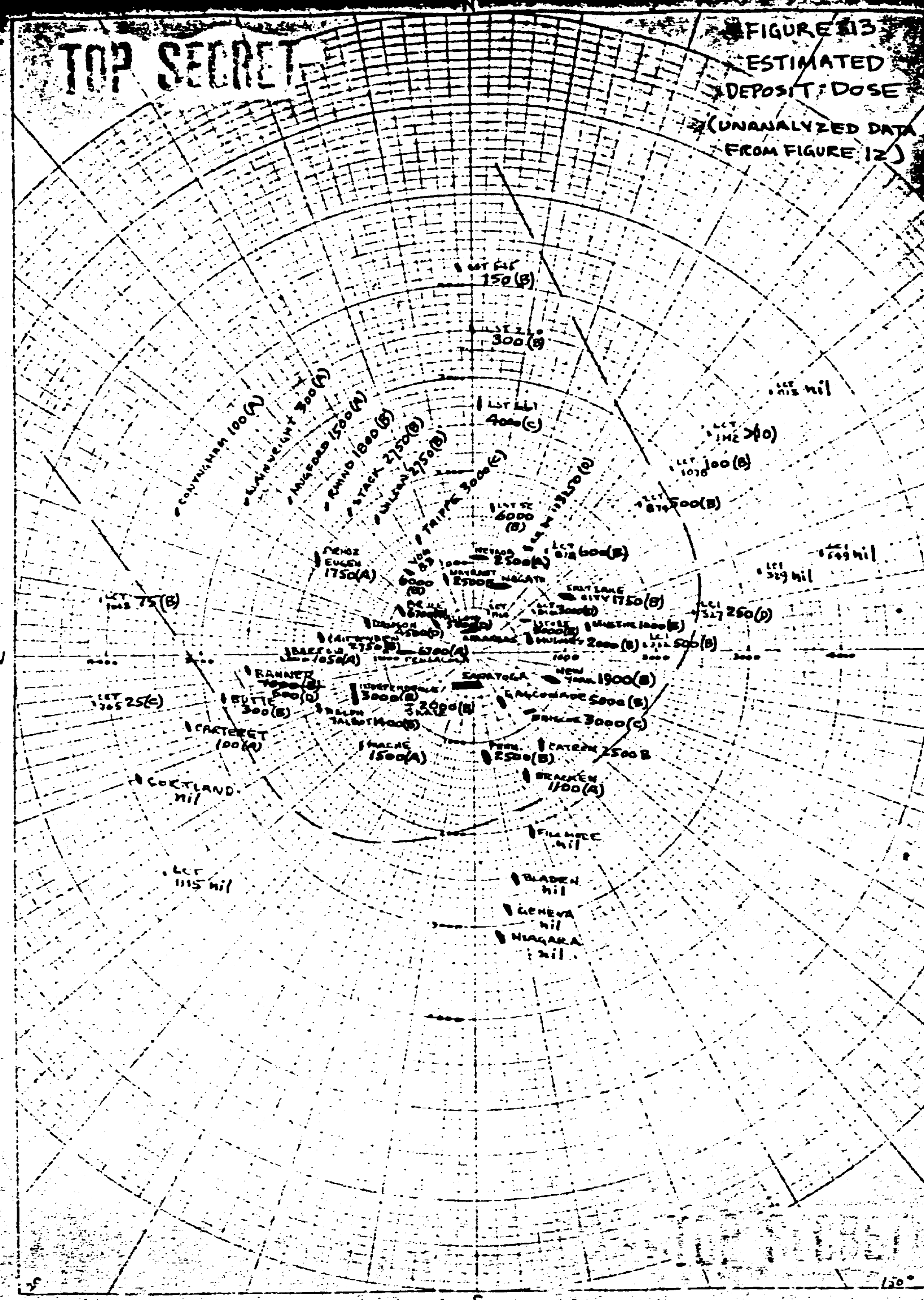

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FIGURE 14
CONTOURS OF DEPOSIT DOSE
(UNANALYZED DATA FROM FIGURE 13)

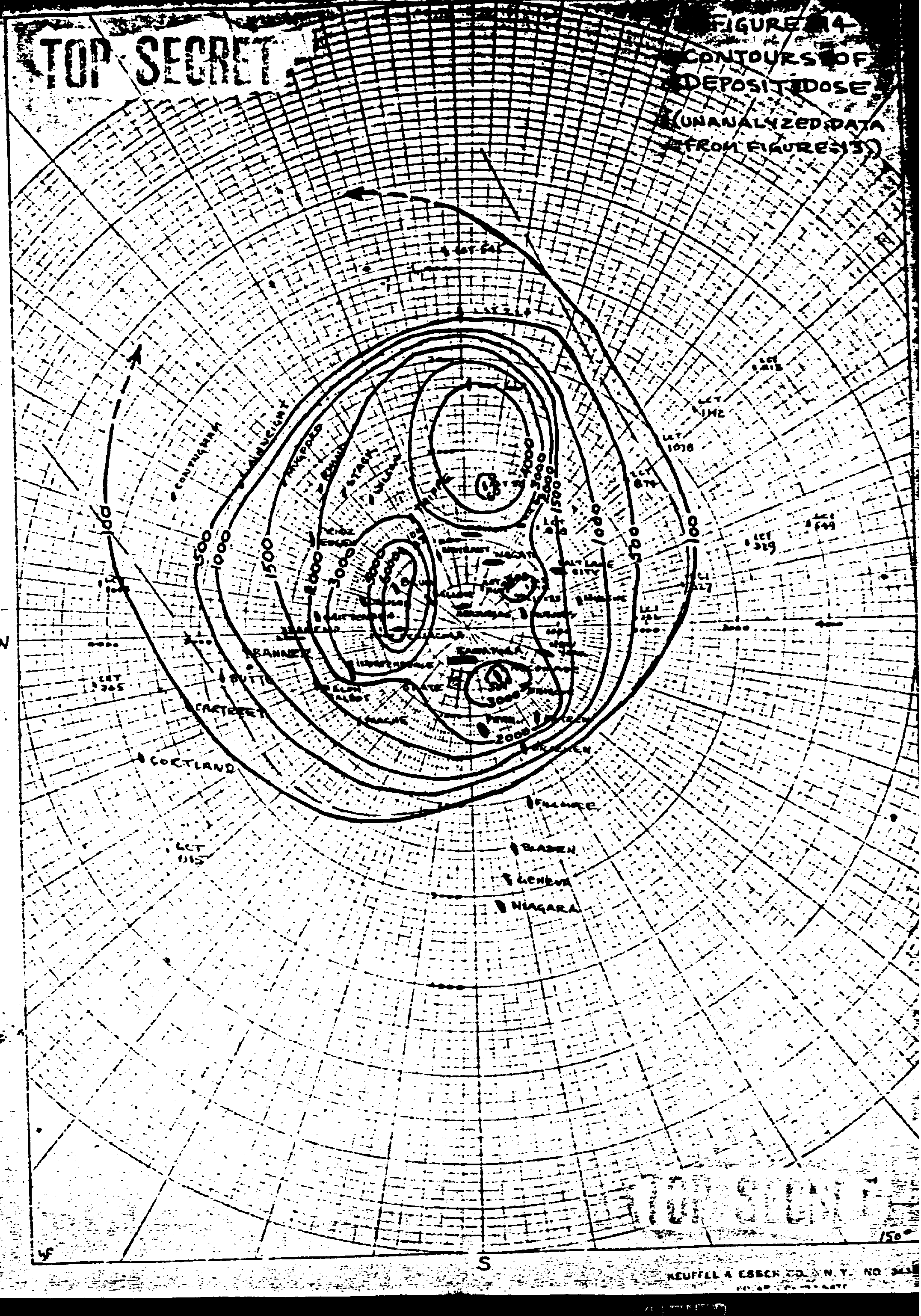

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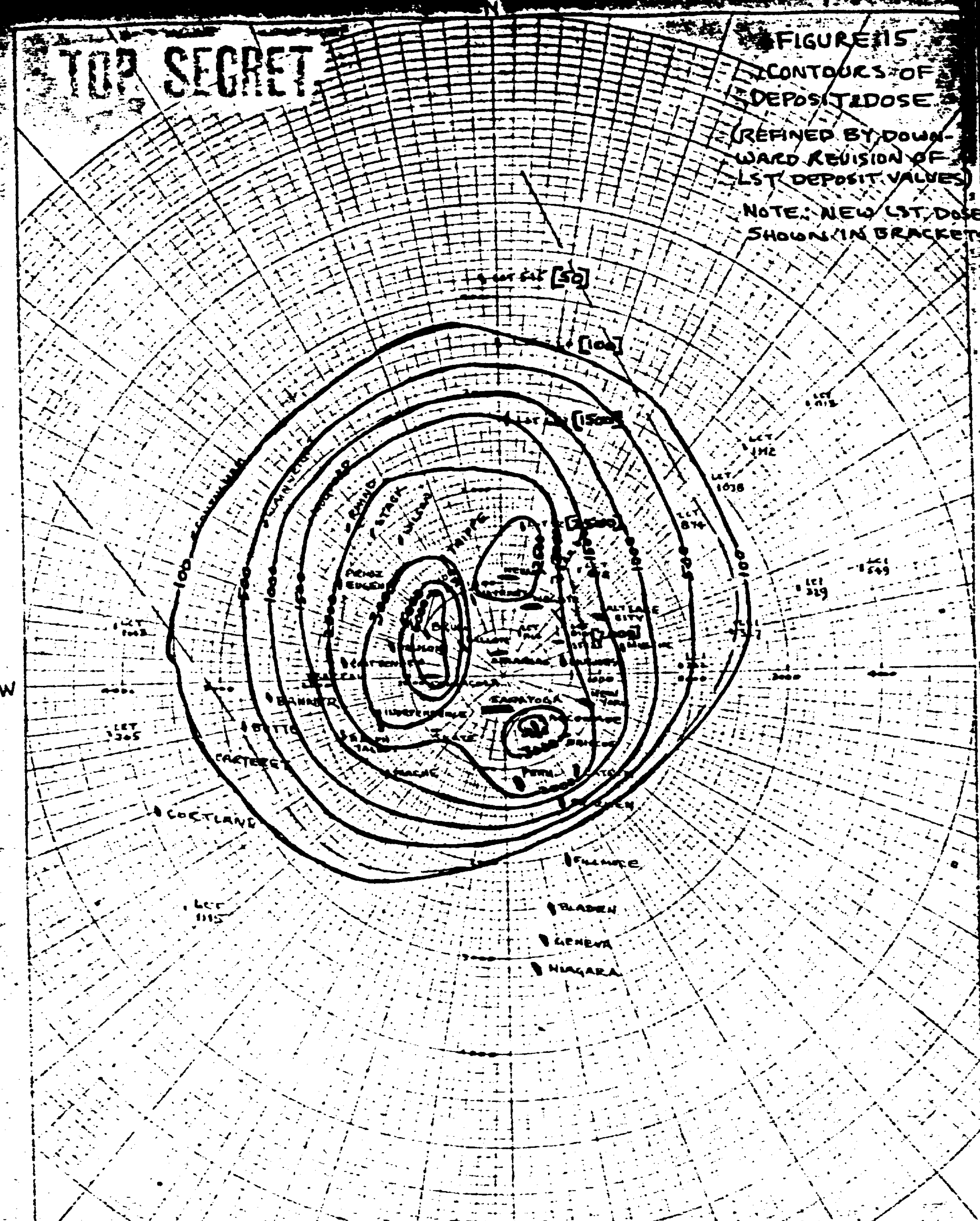
FIGURE 15
CONTOURS OF DEPOSIT DOSE
(REFINED BY DOWNWARD REVISION OF LST DEPOSIT VALUES)
NOTE: NEW LST DOSE SHOWN IN BRACKETS



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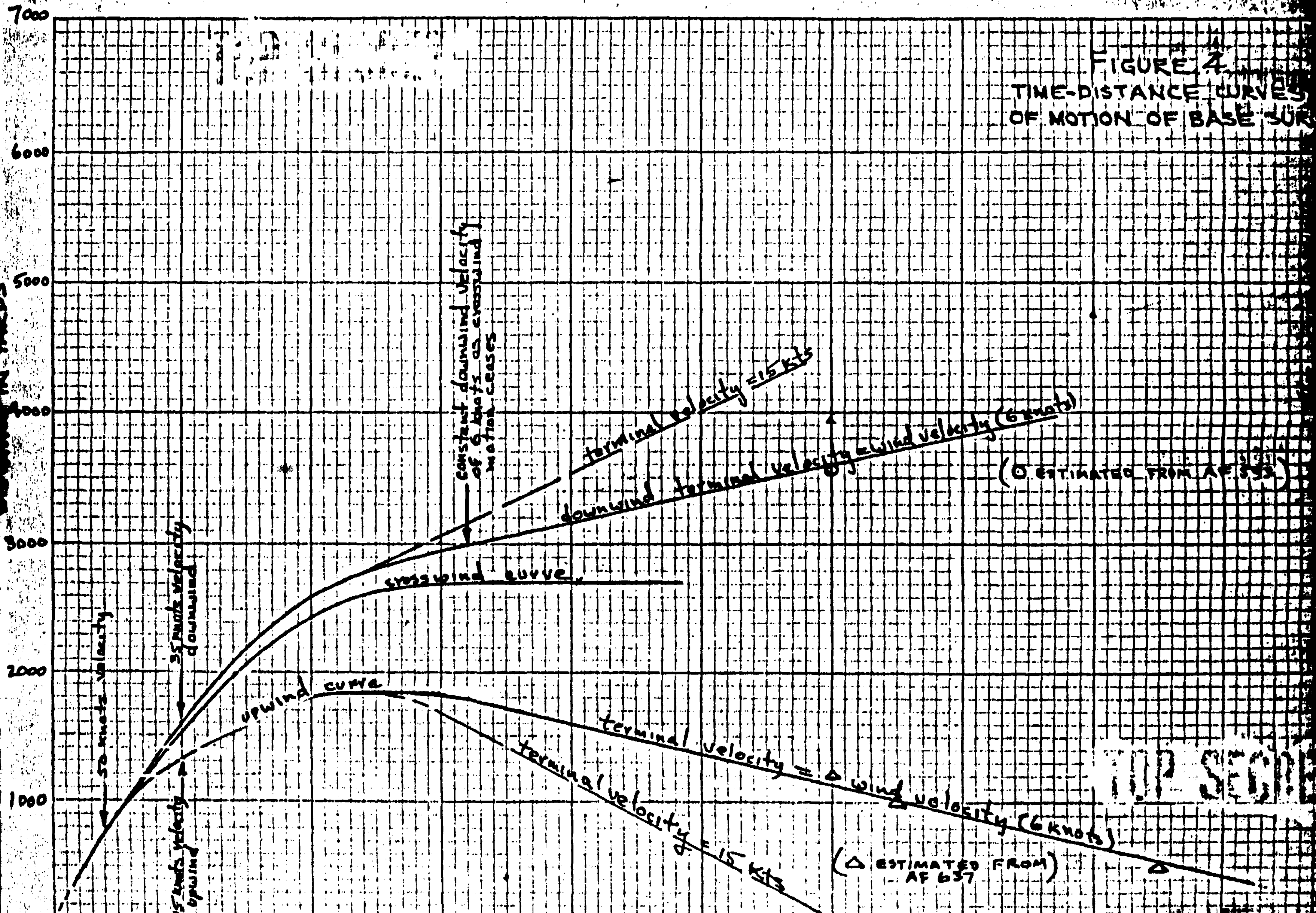
FIGURE 4
TIME-DISTANCE CURVES
OF MOTION OF BASE SUR
7000
6000
5000
4000
3000
2000
1000
terminal velocity = 15 kts
downwind terminal velocity = wind velocity (6 knots)
(O ESTIMATED FROM AF 353)
constant downwind velocity of 6 knots as crosswind motion ceases
crosswind curve
35 knots velocity downwind
50 knots velocity
upwind curve
15 knots velocity upwind
terminal velocity = Δ wind velocity (6 knots)
terminal velocity = 15 kts
(Δ ESTIMATED FROM AF 637)

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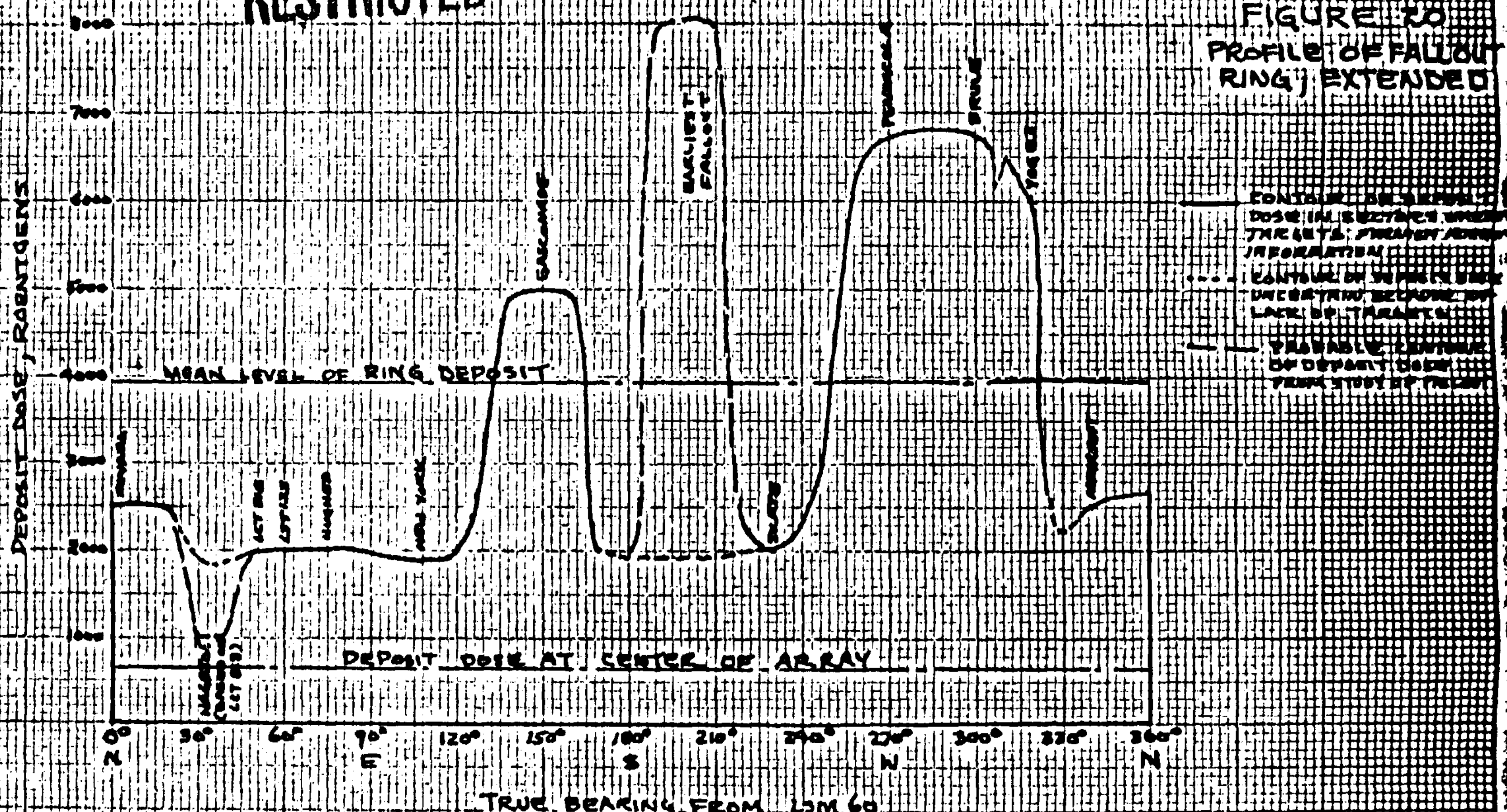
RESTRICTED

FIGURE 20
PROFILE OF FALLOUT RING, EXTENDED



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VESSEL	BADGE NO.	BADGE LOCATION	MEASURED DOSE	REMARKS
NEW YORK (BB34)	3427	PILOT HOUSE (INSIDE) FR.48	2500	
	3432	MOTOR GEN. RM. B-114, FR 77	7.8	
	3433	A-116½ ON AMMO. HOIST	3	
	3434	PAINT LOCKER, FR. 5	120	
	3435	SAIL RM. A-43, FR. 9	105	
	3436	FWD. DISTRIB. BD., FR. 45	2.7	
	3437	AFT. DISTRIB. BD., FR. 78	5.2	
	3438	STBD. ENG. RM.	8.2	
	3439	PORT ENG. RM.	63.2	
	3441	GSK ENGINE STORES	7.7	
	3443	GSK HOLD, A-3, FR. 9	8.3	
	3444	INSIDE NO.1 TURRET	15	
	4634	NO.1 TURRET MAGAZINE	1.2	
NEVADA (BB36)	3453	A-270-1L, PORT	240	
	3454	A-240-L, PANTRY	355	
	3455	A-210-L W.C., FR.6	235	
	3456	D-315-L, STBD.	45	
	3457	RADIO 3	18	
	3458	D-302-L	8.6	
	3459	D-314-L, STBD.	440	
	3460	D-430-T, STBD.	4.9	
	3462	AFT. DYNAMO	3.6	
	3463	A-5101-A	3.3	
	3465	A-606-E	3.7	
	3466	A-302-A	4.6	
	4639	NO. 1 MAGAZINE	1.8	
PENNSYLVANIA (BB38)	3472	S.D. STORES A-105, FR. 98	1800	
	4665	40MM MAG. A-427-M, FR. 50	0.23	
	3476	PLOTTING RM. A-321, FR. 57	3.0	
	3477	OPTICAL SHOP, FR. 55	9.8	
	3478	PILOT HOUSE, FR. 58	1850	
	3480	W.O. PANTRY, FR. 92	195	
	3481	NO 2 14/35 TURRET, INSIDE	9.0	
	3484	NO. 4 TURRET, INSIDE	12.7	
	3485	TWIN 5"/38 FWD. STBD. INSIDE	1700	
	3486	WARDROOM PANTRY, FR. 112	310	
	3488	CPO QTRS. A-605, FR. 18	1600	
	3489	CAPT. OFFICE, FR 128	1850	
	3495	S.D. STORES, A-401, FR 8	1500	
	3497	CREW'S SPACE, A-608, FR 40	137	
	3498	TWIN 5"/38, AFT PORT INSIDE	137	

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FIGURE 21-A

VESSEL	[illegible]	[illegible]	[illegible]	REMARKS
SALT LAKE CITY (CA25)	3499	S.D. STORES, A-507, FR. 6	74	
	3503	SHIPFITTERS STORES FR 133	7.7	
	3505	WINDLASS RM. A-202E, FR.7	1400	
	3506	ENG RM. C-1, DYNAMO PLAT. FR.70	74	
	3507	ENG. RM. C-2, FR.90 PLOT RM.	77	
	3509	PILOT HOUSE, FR.47	1700	
	3510	MN. CIC RM. FR.40	310	
	3511	NO.2 TURRET FR.40	390	
	3512	NO.4 TURRET FR.120 (INSIDE)	1600	
	3514	UNDER TURRET NO.1 OVERHANG	2400	UNSHIELDED BADGE
	3515	OPERATING RM. A-309L, FR.32	74	
	3518	UNDER TURRET NO.4 OVERHANG	1600	UNSHIELDED BADGE
	3519	CPO QTRS. D-206L FR.137	1200	
	3521	EMERG. RADIO RM.	1500	
PRINZ EUGEN (IX 300)		NO DATA		
SKATE (SS 305)	3687	PUMP RM. FR. 51	285	
	3688	CREWS LOCKER FR. 87	1400	
	3689	OFFS QUARTERS FR 40	6800	
	3690	CONTROL ROOM, FR 51	1500	
	3691	CREWS MESS FR. 64	2800	
	3692	AFT. TORP. RM. FR. 117	1400	
	3693	MANEUVERING RM. FR. 102	370	
	3694	FWD ENG. RM. FR. 80	2500	
	3695	STOREROOM FR. 57	190	
	3697	FWD ESCAPE TRUNK	2800	
	3698	CONNING TOWER	1950	
	3700	AFT. TORP. RM. FR. 108	1600	
PARCHE (SS 384)	3701	PYROTECHNIC FR. 56	9	
	3703	MN. GEN. SET NO.2 FR 83	104	
	3704	MOTOR RM. FR. 105	11.2	
	3705	PUMP ROOM FR. 50	19.5	
	3706	FWD TORPEDO RM. FR 35	88	
	3707	AFTER TORPEDO RM FR. 115	190	
	3708	CONNING TOWER	290	

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FIGURE 21-C

VESSEL	BADGE NO.	BADGE LOCATION	MEASURED DOSE	REMARKS
INDEPENDENCE	3599	SD STORES, A-202-A, FR. 8	1250	
(CVL 22)	3600	A-302-A, FR. 7	210	
	3601	SD STORES, A-401-A, FR. 6	380	
	3602	PUMP RM., FR. 10	14	
	3604	SD STORES, A-504-A, FR. 22	20	
	3605	C&S STORE, FR. 24	195	
	3606	WARDRM. MESS, A-105-L, FR. 35	225	
	3607	BOMB STOWAGE A-511-M FR. 43	4.2	
	3608	RADIO CENTRAL, A-420-C, FR. 56	7.2	
	3609	REPAIR PARTY LOCKER, FR. 84	240	
	3610	CREWS BERTHING, C-201-L FR. 106	400	
	3611	AFT. GYRO RM. FR. 104	7	
	3612	MAIN ISSUE RM. C-410, FR. 122	30	
	3613	CPO HEAD, C-208-L, FR. 150	1300	
	3614	AVIATION STORES, C-415A, FR. 139	200	
	3615	CPO MESS, C-205-2L, FR. 135	260	
	3616	WASTE STORES, C-417, FR. 148	260	
	3617	CREW LIBRARY, C-313-C, FR. 147	1300	
	3618	CREW BERTHING C-201-EL FR. 144	2650	
PENSACOLA	3522	INSIDE NO. 1 TURRET B 1/55, FR. 22	1900	
(CA24)	3523	PILOT HOUSE, STBD., FR. 40	2500	
	3524	OUTSIDE NO. 1 TURRET, PORT, FR. 25	6700	UNSHIELDED BADGE
	3525	—		
	3526	CAPTS. CABIN, FR. 42	2800	
	3527	HDLG. RM. A-404-M, FR. 20	175	
	3528	CREWS SPACE, C-201-L, FR. 65	2350	
	3529	WINDLASS RM. A-202-E, FR. 7	2450	
	3530	SD STORES, A-502-A, FR. 9	1800	
	3531	CENTRAL STATION FR. 40	4.7	
	3532	SD STORES, A-501-M	2500	
	3534	MAIN ISSUE RM. FR. 40	1400	
	3535	PILOT HOUSE, FWD. FR. 90	2600	
	3536	PILOT HOUSE, PORT, FR. 40	3050	
	3537	CREW SPACE, FR. 102	1900	
	3538	SD ORD STORES D-504-A, FR. 104	6.1	
	3540	NO. 4 TURRET FR. 118 (INSIDE)	1700	
	3541	RADAR TRANS. RM. FR. 87	3450	
	3542	PLOT RM. FR. 100	3400	
	3543	GYRO RM. D-501 FR. 100	34	
	3544	OUTSIDE NO. 4 TURRET FR. 120	10,000	UNSHIELDED BADGE
	3545	ENG. RM. C-2 FR. 90	1000	
	3546	RADIO CONTROL RM. FR. 103	2300	
	3547	8" SHELL STOWAGE FR. 120 STBD.	1900	
	3548	8" SHELL STOWAGE FR. 120 PORT	1750	
	3550	OFFICERS PANTRY FR. 57	2600	
	3551	ENG. RM. C-1 FR. 65	1750	

RESTRICTED

FIGURE 21-B

VESSEL	BADGE NO.	BADGE LOCATION	MEASURED DOSE	REMARKS
BANNER	3738	No. 2 HOLD, 1st PLAT. FR. 108	91	
(APA 60)	3739	S.D. STORES, PORT, FR. 20	95	
	3740	S.D. STORES, STBD., FR. 20	92	
	3741	FWD. MACHINERY SPACE FR. 76	9	
BARROW	3787	AUX. MACHINE SHOP	98	
(APA 61)	3788	NO. 1 HOLD, PORT	115	
	3789	G.S.K. PORT	115	
	3790	BOSN LOCKER	120	
	3791	FR. 143, MIDSHIPS	105	
	3793	CREW BERTHING	105	
	3794	CREWS MESS	120	
	3795	DENTAL OFFICE	123	
	3796	No. 2 HOLD, MIDSHIPS	110	
	3797	WHEEL HOUSE, FR. 62	120	
	3798	BOSN LOCKER, PORT	115	
BRACKEN	3850	NO. 2 HOLD, PORT, FR. 116	185	
(APA 64)	3851	ORD. STORES, C-303-A, FR. 143 P.	360	
	3852	TROOP T&S, MN. DK. FR. 165 PORT	420	
	3854	CREW & TROOP MESS, MN. DK. FR. 73 P.	285	
	3855	CREW & TROOP MESS, MN. DK. FR. 73 S.	390	
	3857	No. 1 HOLD, PORT, FR. 48 (TANKTOP)	31.5	
	3858	No. 6 HOLD, STBD. FR. 48 (TANKTOP)	35	
	3859	SD STORES, PORT FR. 20 A-302A	102	
	3860	SD STORES, STBD. FR. 20 A-302A	100	
	3863	BOSN STORE A-0101A FR. 5	140	
	3864	WHEEL HOUSE, PORT, FR. 62	450	
BRISCOE	3744	S.D. STORES, FR. 18, PORT	450	
(APA 65)	3745	20mm GUNTUB, FR. 78, PORT	6200	UNSHIELDED BADGE
	3747	CREW BERTHING, FR. 48, STBD	2100	
	3748	CARGO HOLD NO. 3, STBD.	1500	
	3749	CARGO HOLD NO. 2, 1st PLAT FR. 98	2200	
	3750	CREW & TROOP MESS FR. 75, PORT	2300	
	3751	DENTAL OFFICE, FR. 105	3400	
	3752	AUX MACHINERY SPACE, FR. 80 PORT	170	
	3753	SD STORES, FR. 18, STBD.	470	
	3755	20mm GUN TUB, FR. 78, STBD.	8000	UNSHIELDED BADGE
	3756	BOSN STORES FR. 151	2000	
	3758	CREW BERTHING, FR. 48, STBD	2000	
	3759	NO. 1 CARGO HOLD, FR. 46, PORT	1600	

RESTRICTED

FIGURE 21-D

VESSEL	NO.	LOCATION	DOSE	REMARKS
BRULE	3760	S.D. STORES, FR 20, PORT	2600	
(APA 66)	3761	S.D. STORES, FR 20, STBD	2000	
	3762	BOSN STORES, FR 5	2500	
	3763	NO. 1 CARGO HOLD, FR 50 PORT	2550	
	3764	NO. 1 CARGO HOLD, FR 50 STBD	2350	
	3765	CREW BERTHING, FR 50 PORT	4800	
	3766	CREW BERTHING, FR 50 STBD	5200	
	3767	WHEEL HOUSE, FR 62	9000	
	3768	MOTOR GEN. RM. FR 85	15000	
	3769	S.D. STORES, FR 130	2000	
	3770	NO. 2 HOLD, 1st PLAT. FR 124	3260	
BUTTE	3803	BOSN STORES, FR 5, PORT	87	
(APA 68)	3804	AUX. MACH. SPACE FR 84	48	
	3805	S.D. STORES, FR 20, STBD	28	
	3806	S.D. STORES, FR 20, CENTER	18	
	3807	S.D. STORES, FR 20, PORT	30	
CARTERET	3771	S.D. STORES, FR 20, STBD	12.5	
(APA 70)	3772	S.D. STORES, FR 20, PORT	29	
	3773	FWD. MACH. SPACE, FR 75	4.6	
	3774	ORD. STORES, FR 143	6.8	
	3775	RADIO I, FR 77	90	
	3776	NO. 2 HOLD, FR. 124	13	
CATRON	3865	S.D. STORES, PORT, FR. 20	300	
(APA 71)	3866	BOSN STORES, FR. 5	1600	
	3867	S.D. STORES, STBD FR 20	430	
	3869	MOTOR GEN. RM. FR. 85	1900	
	3870	NO. 2 HOLD FR 116	1450	
	3871	ORD. STORES, 40mm AMM.	1600	
	3873	TROOP HEAD, STBD, FR. 165	1800	
	3874	TROOP HEAD, ~~STBD~~ PORT, FR. 165	1800	
	3875	WHEEL HOUSE, FR 62	1700	
	3876	RADAR CONTROL RM. FR. 64	130	
	3877	CREW & TROOP MESS FR. 73 STBD.	1900	
	3878	BOOBY HATCH, FR. 20	1920	
	3879	CREW & TROOP MESS, FR 73 PORT	368	

RESTRICTED

FIGURE 21-E

VESSEL	BADGE NO.	BADGE LOCATION	MEASURED DOSE	REMARKS
CRITTENDEN (APA-77)	3813	CREW QUARTERS, FR 38, STBD	1900	
	3814	CREW QUARTERS, FR. 48, PORT	1930	
	3815	No. 1 HOLD, FR. 48, PORT	440	
	3816	No. 1 HOLD, FR. 48, STBD	395	
	3817	C & TROOP MESS, FR. 75	2100	
	3818	S.D. STORES, FR. 18, STBD.	280	
	3819	S.D. STORES, FR. 18, PORT	1780	
	3821	WHEEL HOUSE, FR. 62	370	
	3824	DENTAL OFFICE, FR. 105	2900	
	3825	No. 2 HOLD, 1st PLAT.	2100	
	3826	ENGINE ROOM	262	
	3827	AUX MACH SPACE, FR. 89	208	
	3828	ORD. STORES, 40mm AMM. FR 143	195	
DAWSON (APA 79)	3880	S.D. STORES, FR. 20, PORT	1880	
	3881	S.D. STORES, FR. 20, STBD.	495	
	3882	BOSN STORES, FR. 5	1800	
	3883	No. 1 CARGO HOLD FR 48 PORT	1950	
	3884	No. 1 CARGO HOLD FR 48 STBD.	1800	
	3885	MOTOR GEN. RM., FR. 85	2550	
	3886	No. 2 HOLD, FR. 114 PORT	2100	
	3887	BOOBY HATCH, FR. 20, STBD.	3000	
	3888	ORD. STORES, 40mm AMM, FR. 143	2600	
	3889	TROOP BERTHING, FR. 165, PORT	2750	
	3890	TROOP BERTHING, FR. 165, STBD.	2100	
	3891	WHEEL HOUSE, FR. 62	3500	
	3892	RADAR CONTROL RM. FR. 34	3000	
	3893	MESS HALL, FR. 73, PORT	3700	
	3894	MESS HALL, FR. 73, STBD.	2300	
FALLON (APA 81)	3777	S.D. STORES, FR. 19, PORT	1700	
	3778	S.D. STORES, FR. 19, STBD.	2050	
	3781	CARGO HOLD, STBD.	5200	
	3782	AUX MACH. SPACE, FR. 89	1250	
	3784	TROOP BERTHING	4800	
	3785	S.D. STORES, FR. 130	3500	
GASCONADE (APA 85)		NO DATA		

RESTRICTED

FIGURE 21 F

VESSEL	BADGE NO.	BADGE LOCATION	MEASURED DOSE	REMARKS
CORTLAND	3808	S.D. STORES, FR. 20	4.7	
(APA 75)	5001	S.D. STORES, FR. 130	1.2	
	3810	PILOT HOUSE, FR. 60	3.2	
	3811	MOTOR GEN. RM., FR. 85	4.7	
	4998	BOS'N STORES, FR. 5, PORT	1.0	
FILLMORE	3895	BOS'N STORES, FR. 5, PORT	2.5	
(APA 83)	3896	S.D. STORES, FR. 20, PORT	2.1	
	3897	S.D. STORES, FR. 20, STBD.	3.2	
	3898	MOTOR GEN. RM. FR. 85, PORT	2.8	
	3899	S.D. STORES, FR. 130, PORT	3.6	
BLADEN	3846	FWD. MACH. SPACE, FR. 75, STBD.	2.0	
(APA 63)	3847	ORD. STORES, 40mm AMM. FR 143 P	2.0	
	3848	RADIO RM FR 77, PORT	2.0	
	5033	S.D. STORES, FR. 20, STBD.	0.20	
	5034	S.D. STORES, FR 20, PORT	0.29	
	5038	NO. 2 HOLD, 1ST PLAT, PORT	0.40	
NIAGARA	5089	MOTOR GEN. RM., FR. 85	0.20	
(APA 87)	5090	S.D. STORES, FR. 20, STBD.	0.08	
	5091	S.D. STORES, FR. 20, PORT	0.12	
	5093	S.D. STORES, FR. 130	0.11	
GENEVA (APA 86)		NO DATA		
CONYNGHAM	3328	BOS'N STORES, FR. 4	72	
(DD 371)	3329	NO. 1 5" MOUNT, FR. 32	220	UNSHIELDED BADGE
	3332	PILOT HOUSE, FR. 62	105	
	3333	NO. 1 MAGAZINE, FR. 37	10	
	3334	PROJECTILE HDL'G RM., FR. 157	17.5	
	3335	GENERAL STORES, FR. 190	71	
MUGFORD	3318	INSIDE NO. 1 5" MOUNT, FR. 32	1750	
(DD 389)	3320	NO. 1 HANDLING ROOM,	190	
	3321	BOS'N STORES, FR. 4	420	
	3322	NO. 1 MAGAZINE, FR. 28	36	
	3323	BULK STORES, A-407A, FR. 21	63	
	3324	TORPEDO SHACK, FR. 121	1850	
	3327	GAS MASK STORAGE, FR. 182	220	
HUGHES	3376	INSIDE NO. 2 5" HDL'G RM. FR. 75	1800	
(DD 410)	3378	INSIDE MK. 37 GUN DIRECTOR	4275	
	3379	TORPEDO SHACK, FR. 105	1750	
	3380	MK. 27 TORPEDO DIRECTOR, FR. 67	4900	UNSHIELDED BADGE
	3383	INSIDE 5" GUN DIRECTOR, FR. 67	2400	
	3384	GAS MASK STOWAGE, FR. 179	470	
	3385	BOS'N STORES, FR. 2	2600	

RESTRICTED

FIGURE B1-6

VESSEL	BADGE NO.	BADGE LOCATION	MEASURED DOSE	REMARKS
RALPH TALBOT	3386	GUN DIRECTOR, FR. 62 (INSIDE)	1600	
(DD 390)	3387	BOS'N STORES, FR. 4	3415	
	3389	A-204L, FR. 36	1500	
	3390	NO. 1 HDL'G. RM. FR. 33	250	
	3391	SUPPLY OFFICE, FR. 70	1600	
	3392	NO. 1 MAGAZINE, FR. 28	115	
	3393	RADIO CONTROL, FR. 60	350	
	3394	TORPEDO SHACK, FR. 121	1600	
	3395	PILOT HOUSE, FR. 60	1750	
	3397	CPO QUARTERS, FR. 21	1500	
	3398	GENERAL STORES, FR. 190	1400	
	3399	CREWS QUARTERS, FR. 160	1650	
	3400	GAS MASK STORAGE, FR. 181	420	
MAYRANT	3352	BOS'N STORES, FR. 4	2700	
(DD 402)	3353	NO. 1 5" MOUNT, FR. 32 (INSIDE)	3500	
	3354	NO. 1 HANDLING RM., FR. 29	2250	
	3356	CIC RM. FR. 60	4300	
	3357	PILOT HOUSE, FR. 61	4900	
	3358	5" GUN DIRECTOR, FR. 64	> 8000	UNSHIELDED BADGE
	3359	CREWS QUARTERS, FR. 177	5600	
	3360	GAS MASK STORAGE, FR. 182	2500	
	3361	GENERAL STORES, FR. 190	3350	
	3362	NO. 1 MAGAZINE, FR. 37	350	
	3363	BULK STORES, FR. 21	1600	
	3364	PROJECTILE HDL'G RM., FR. 157	1400	
TRIPPE	3365	NO. 1 5" MOUNT, FR. 32 (INSIDE)	3550	
(DD 403)	3366	5" GUN DIRECTOR, FR. 64	3900	
	3367	NO. 1 HDL'G. RM.	1925	
	3368	BOS'N STORES, FR. 4	2600	
	3370	ENG. STORES A-302, FR. 21	1925	
	3371	TORPEDO SHACK, FR. 121	5200	
	3372	PROJECTILE HDL'G. RM. FR. 158	1600	
	3373	40 MM MOUNT	4900	UNSHIELDED BADGE
	3374	GAS MASK STOWAGE, FR. 192	1750	
RHIND (DD 404)		NO DATA		

RESTRICTED

FIGURE 21-H

VESSEL	BADGE NO.	BADGE LOCATION	RECORDED DOSE	REMARKS
STACK	3299	NO. 1 5" GUN DIRECTOR, FR. 64	2800	
(DD406)	3300	NO. 1 5" HDLG ROOM	1400	
	3301	BOS'N STORES, FR. 4	1750	
	3302	NO. 2 5" MAGAZINE, FR. 28	250	
	3303	BULK STORES, A-402, FR. 2	300	
	3304	TORPEDO SHACK, FR. 121	2100	
	3305	PROJECTILE HDLG. RM., FR. 158	1800	
WILSON	3308	NO. 1 5" MOUNT, FR. 32	2015	
(DD408)	3309	5" GUN DIRECTOR, FR. 64	4650	
	3310	NO. 1 HDLG. RM.	2000	
	3311	BOS'N STORES, FR. 4	2300	
	3312	NO. 2 MAGAZINE, FR. 28	250	
	3313	BULK STORES, A-402, FR. 2	480	
	3314	TORPEDO SHACK, FR. 121	3600	
	3315	PROJECTILE HDLG RM., FR 158	2300	
	3316	40 mm MOUNT	7600	UNSHIELDED BADGE
	3317	GAS MASK STORAGE, FR 182	2750	
MUSTIN	3336	CIC RM A-0201, FR 60	280	
(DD 413)	3337	CREWS QUARTERS, FR. 178	400	
	3339	NO. 1 HDLG RM., FR. 25	235	
	3340	CPO QUARTERS A-109, FR. 21	1400	
	3342	TORPEDO DIRECTOR, MK. 27	2000	UNSHIELDED BADGE
	3344	NO. 1 5" MOUNT, FR. 30	1600	
	3346	5" PDR RM A-406M, FR. 38	270	
	3347	SUPPLY OFFICE, FR 61	318	
	3348	BOS'N STORES, FR. 2	1600	
	3349	PROJECTILE HDLG RM. FR. 144	250	
	3350	NO. 2 MAGAZINE, FR. 37	79	
	3351	CREWS QUARTERS, C-203, FR 162	360	
WAINWRIGHT	3287	NO. 1 5" MOUNT, FR. 32	195	
(DD 419)	3288	A-101A, FR. 4, PORT	160	
	3289	NO. 1 HDLG RM, A-104, FR 25	95	
	3290	A-303A, FR. 16	100	
	3292	INSIDE MK 37 DIRECTOR, FR. 64	165	
	3293	C-31 A, FR. 192	71	
	3294	TORPEDO WORKSHOP, FR. 109	340	
	3295	MK 37 DIRECTOR, FR. 63	166	UNSHIELDED BADGE
	3296	B-4-1, FR. 135	27	
	3297	A-406-M, FR. 37	16	

RESTRICTED

FIGURE 21-1

VESSEL	BADGE NO.	BADGE LOCATION	MEASURED DOSE	REMARKS
LST 523	3196	BILGE CONTROL RM. FR.15	1615	
	3197	CONTROL RM. FR.9, OUTBD RACK	1600	
	3198	GENERAL STORES, A-312A, FR.24	1650	
	3199	TROOP BERTHING, A-214L, FR.24 P	2000	
	3200	MAIN ENG. RM. B-406ET, FR.32	1925	
	3201	AUX ENG. RM. B-301ET, FR.28	1825	
	3202	MN. ENG. RM. B-406ET, FR.34	1700	
	3203	40mm AMM. FR.54, INBD AFT BHD.	1575	
	3204	SKY LOOKOUT, PORT	4000	UNSHIELDED DOSE
LST 133		NO DATA		
LST 220	3232	GENERAL STORES A-312A FR.1[illegible]	86	
	3233	AUX ENGINE RM.	17.5	
	3234	PORT LOOKOUT	41	UNSHIELDED BADGE
LST 545	3242	STBD LOOKOUT	145	UNSHIELDED BADGE
	3243	AUXILIARY ENGINE RM.	14	
	3244	BILGE CONTROL RM.	9.6	
LST 661	3237	BILGE CONTROL RM.	113	
	3238	GENERAL STORES	140	
	3239	AUXILIARY ENGINE RM.	160	
LCI(L)327	3247	PILOT HOUSE, A-0201C, FR.35	72	
	3248	TROOP BERTHING A-205L, FR.48	65	
	3249	STORES SOUND EQUIP., FR.30	67	
	3250	ENGINE RM. B-1, FR.76	47	
	3251	TROOP BERTHING, C-201L, FR.90	74	
LCI(L)329	4441	PILOT HOUSE A-0201C, FR.55	0.7	
	3253	TROOP BERTHING A-205L, FR.52	2.8	
	3254	STORES SOUND EQUIP. FR.30	2.6	
	4444	ENGINE RM. B-1, FR.76	1.9	
	3256	TROOP BERTHING, C-201L, FR.88	2.4	
LCI(L)332	3257	PILOT HOUSE	167	
	3259	TROOP BERTHING, A-205L FR.52	175	
	3260	ENGINE RM. B-1, FR.76	79	
	3261	FWD. COMPARTMENT	167	
LCT 705	3156	PILOT HOUSE	40	
	3157	CREWS QUARTERS	29	
	3158	ENGINE ROOM	14	

RESTRICTED

FIGURE 21-J

VESSEL	BADGE NO	BADGE LOCATION	MEASURED DOSE	REMARKS
LCT 816		NO DATA		
LCT 818	3167	CREWS QUARTERS	1650	
	3168	ENGINE ROOM	345	
	3170	BOS'N STORE LOCKER	1925	
LCT 874	3172	CREWS QUARTERS	233	
	3175	PAINT LOCKER	266	
LCT 1013	3146	PILOT HOUSE	240	
	3147	OFFICER'S QUARTERS	92	
	3148	ENGINE ROOM	79	
	3150	PAINT LOCKER	86	
LCT 1078	3151	PILOT HOUSE	102	
	3152	CREWS QUARTERS	31.5	
	3153	ENGINE ROOM	17.4	
	3154	BOS'N STORE LOCKER	20.5	
LCT 1112	3176	PILOT HOUSE	4.5	
	3177	CREWS QUARTERS	6.3	
	3178	ENGINE ROOM	9.7	INDICATES WATER LI[NE] CONTAMINATION
	3179	BOS'N STORE LOCKER	6.5	
	3180	PAINT LOCKER	5.5	
LCT 1113	3181	PILOT HOUSE	2.7	
	3182	CREWS QUARTERS	2.6	
	3183	ENGINE ROOM	10.6	INDICATES WATER LI[NE] CONTAMINATION
	3184	BOS'N STORE LOCKER	2.75	
ARDC 13 YOG 83		} NO DATA		
LCT 1115 LCT 1114 LCT(L) 549		} NO DATA		

NOTE:
DATA ON SUNKEN VESSELS NOT AVAILABLE.
DATA ON SUBMERGED SUBMARINES NOT INCLUDED IN THIS STUDY.

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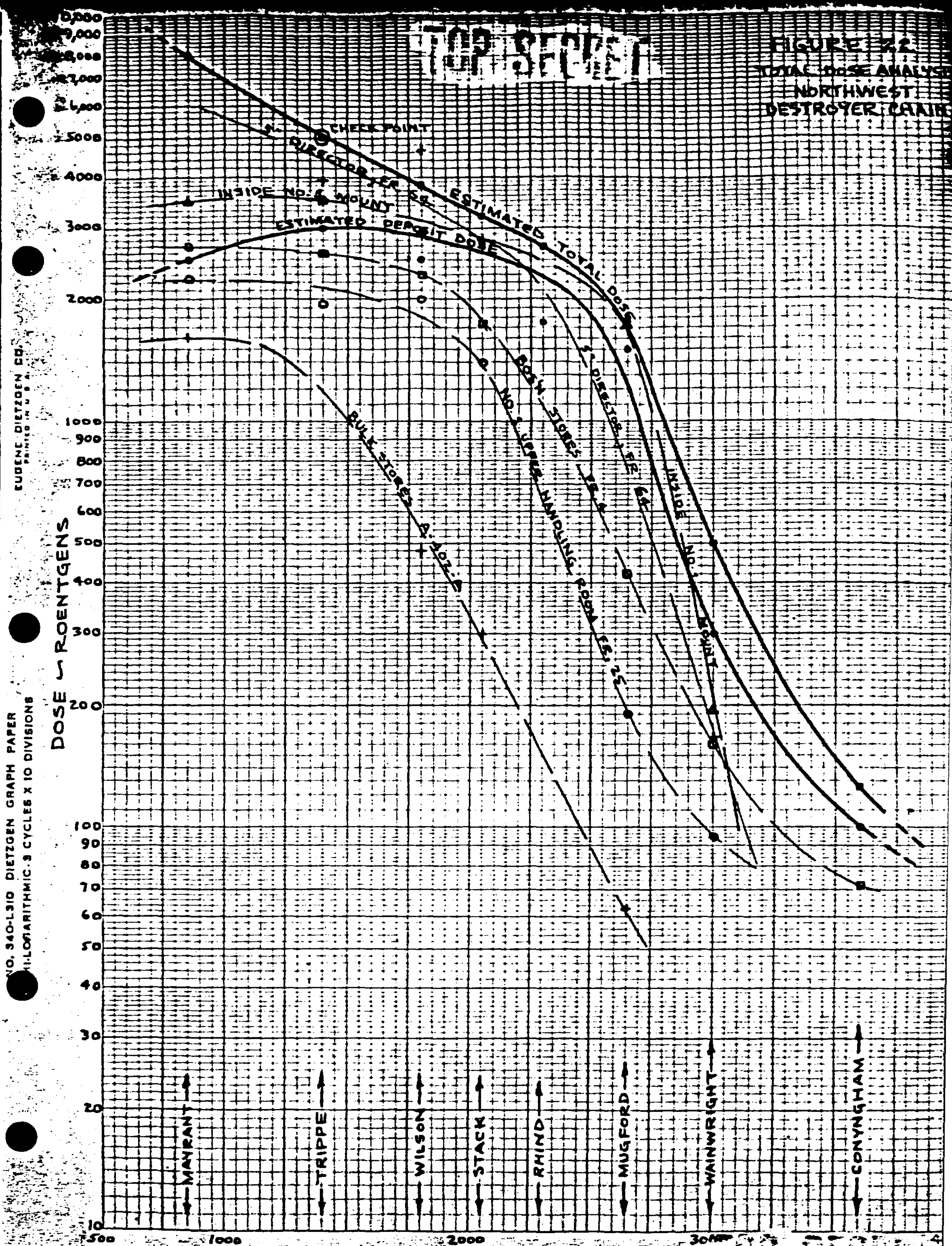
FIGURE 21-[illegible]


TOP SECRET
FIGURE 32
TOTAL DOSE ANALYSIS
NORTHWEST
DESTROYER CHAIN
DOSE ~ ROENTGENS
N. CHECKPOINT
DIRECTOR FR. 52
ESTIMATED TOTAL DOSE
INSIDE NO. 5 MOUNT
ESTIMATED DEPOSIT DOSE
BOS'N. STORES FR. 4
NO. 5 UPPER HANDLING ROOM FR. 32
BULK STORES A-402-A
S. DIRECTOR FR. 56
INSIDE NO. 1 MOUNT
MAYRANT
TRIPPE
WILSON
STACK
RHIND
MUGFORD
WAINWRIGHT
CONYNGHAM
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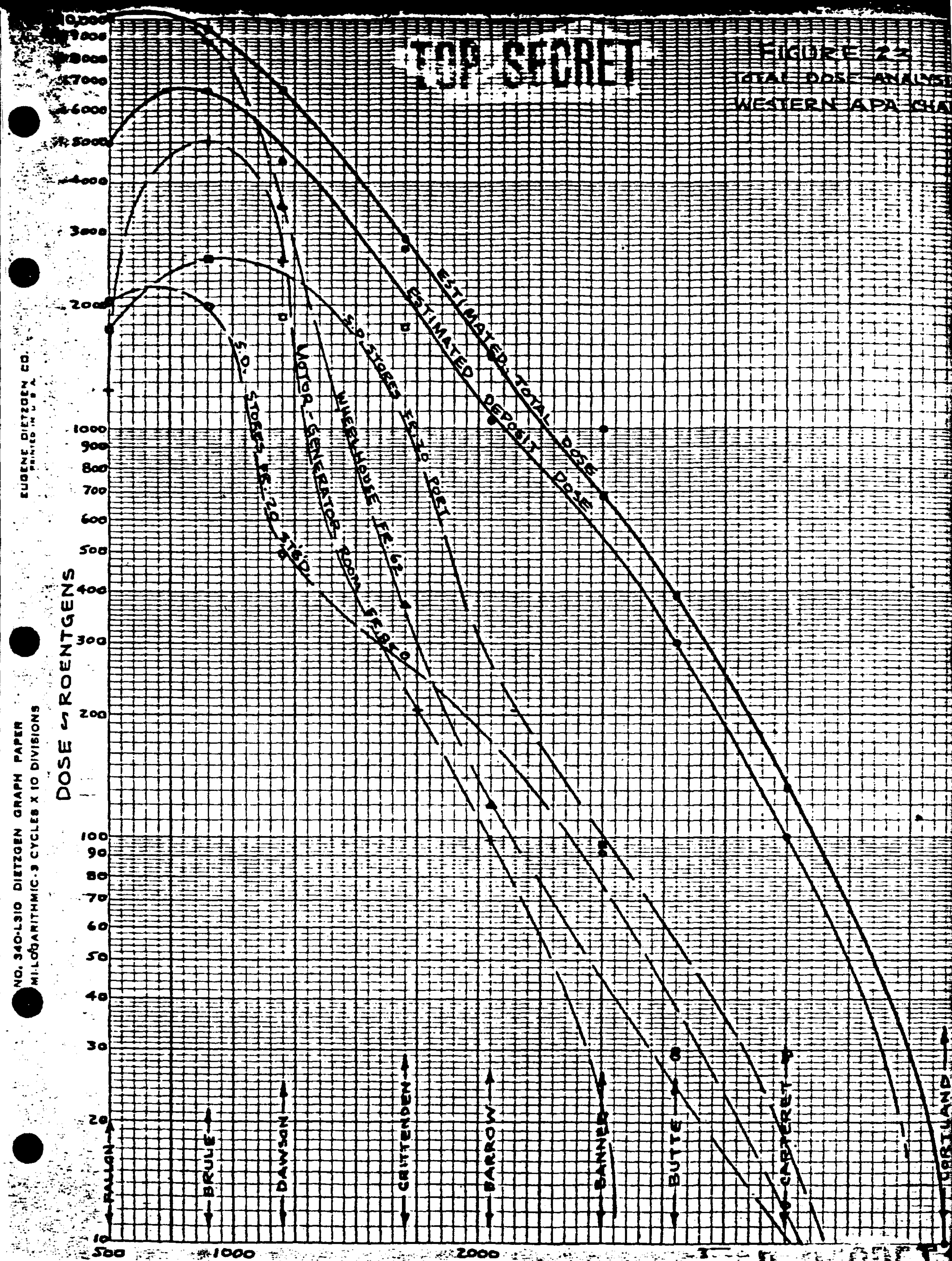

TOP SECRET
FIGURE 23
TOTAL DOSE ANALYS
WESTERN APA CHA
DOSE — ROENTGENS
10,000
9000
8000
7000
6000
5000
4000
3000
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
500
1000
2000
ESTIMATED TOTAL DOSE
ESTIMATED DEPOSIT DOSE
S.P. STORES FR. 10 PORT
WHEELHOUSE FR. 62
MOTOR-GENERATOR ROOM FR. 85
S.D. STORES FR. 20 STBD.
FALLON
BRULE
DAWSON
CRITTENDEN
BARROW
BANNER
BUTTE
CARTERET
CORTLAND
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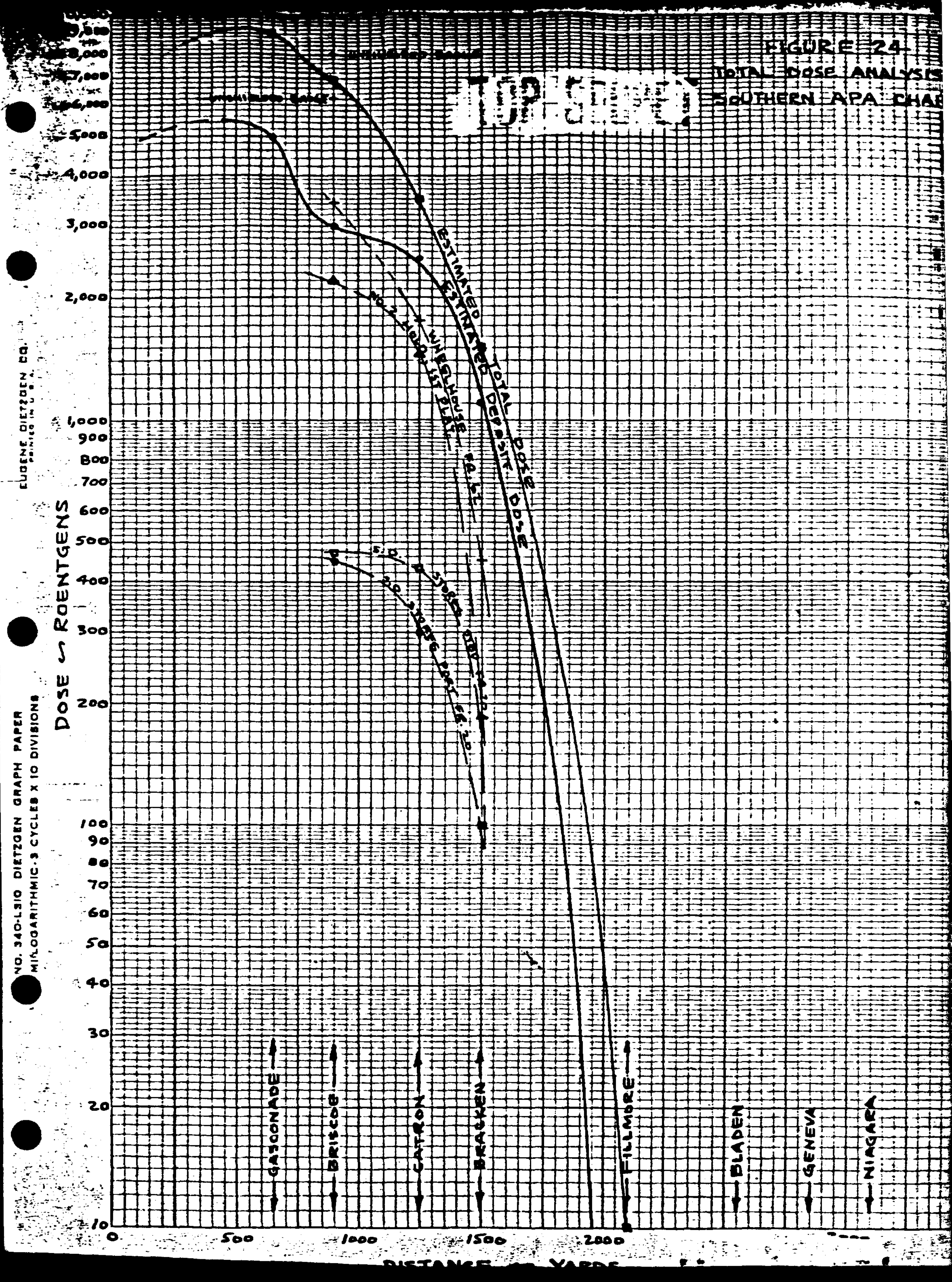
FIGURE 24
TOTAL DOSE ANALYSIS
SOUTHERN APA CHAR
DOSE ~ ROENTGENS
1,000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
2,000
3,000
4,000
5,000
ESTIMATED TOTAL DOSE
ESTIMATED DEPOSIT DOSE
WHEELHOUSE
GASCONADE
BRISCOE
CATRON
BRACKEN
FILLMORE
BLADEN
GENEVA
NIAGARA
0
500
1000
1500
2000
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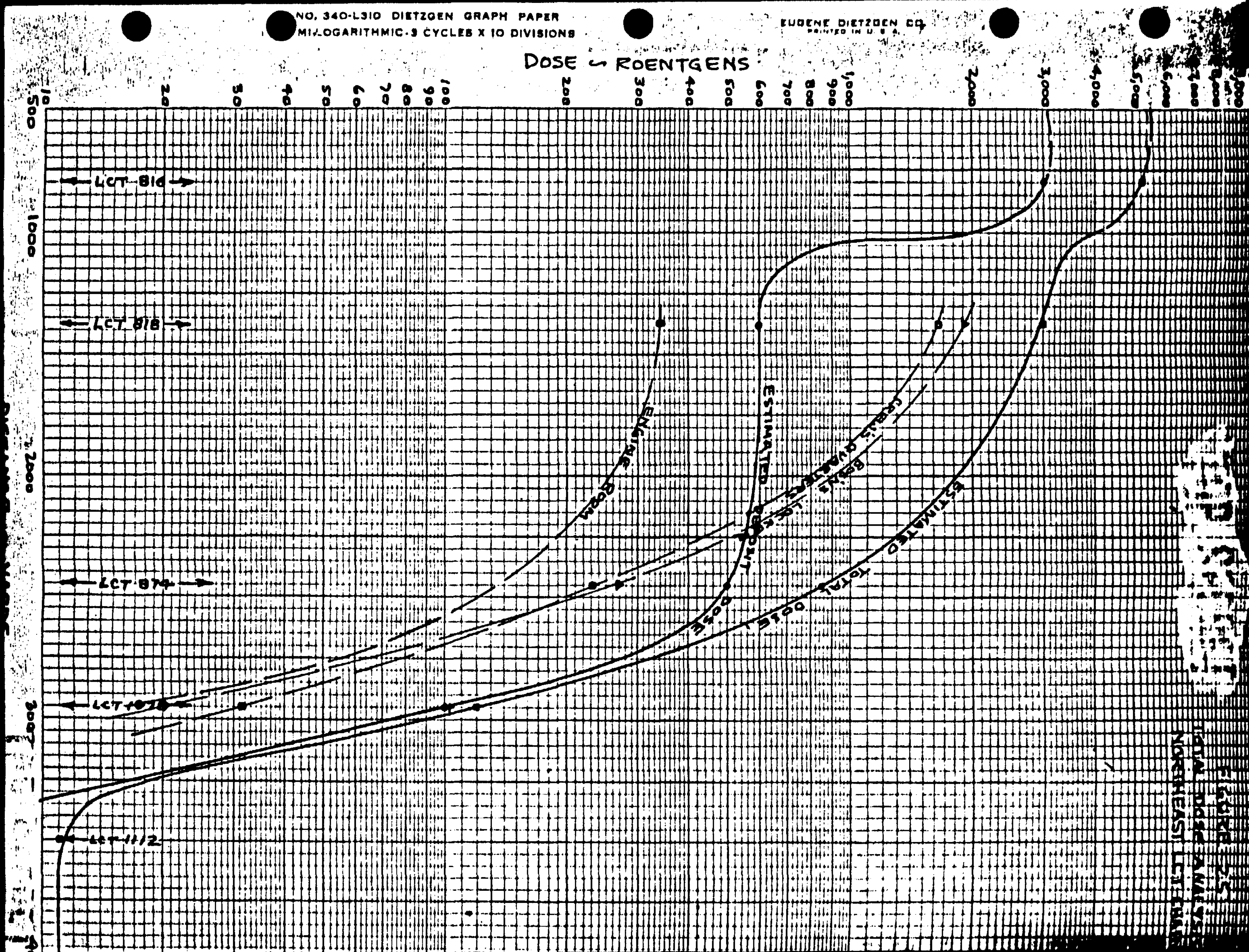
NO. 340-L310 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC-3 CYCLES X 10 DIVISIONS
EUGENE DIETZGEN CO.
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DOSE ~ ROENTGENS
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1,000
2,000
3,000
4,000
5,000
500
1000
2000
LCT 816
LCT 818
LCT 874
LCT 1112
ESTIMATED TOTAL DOSE
ESTIMATED DOSE
CREW'S QUARTERS
ENGINE ROOM

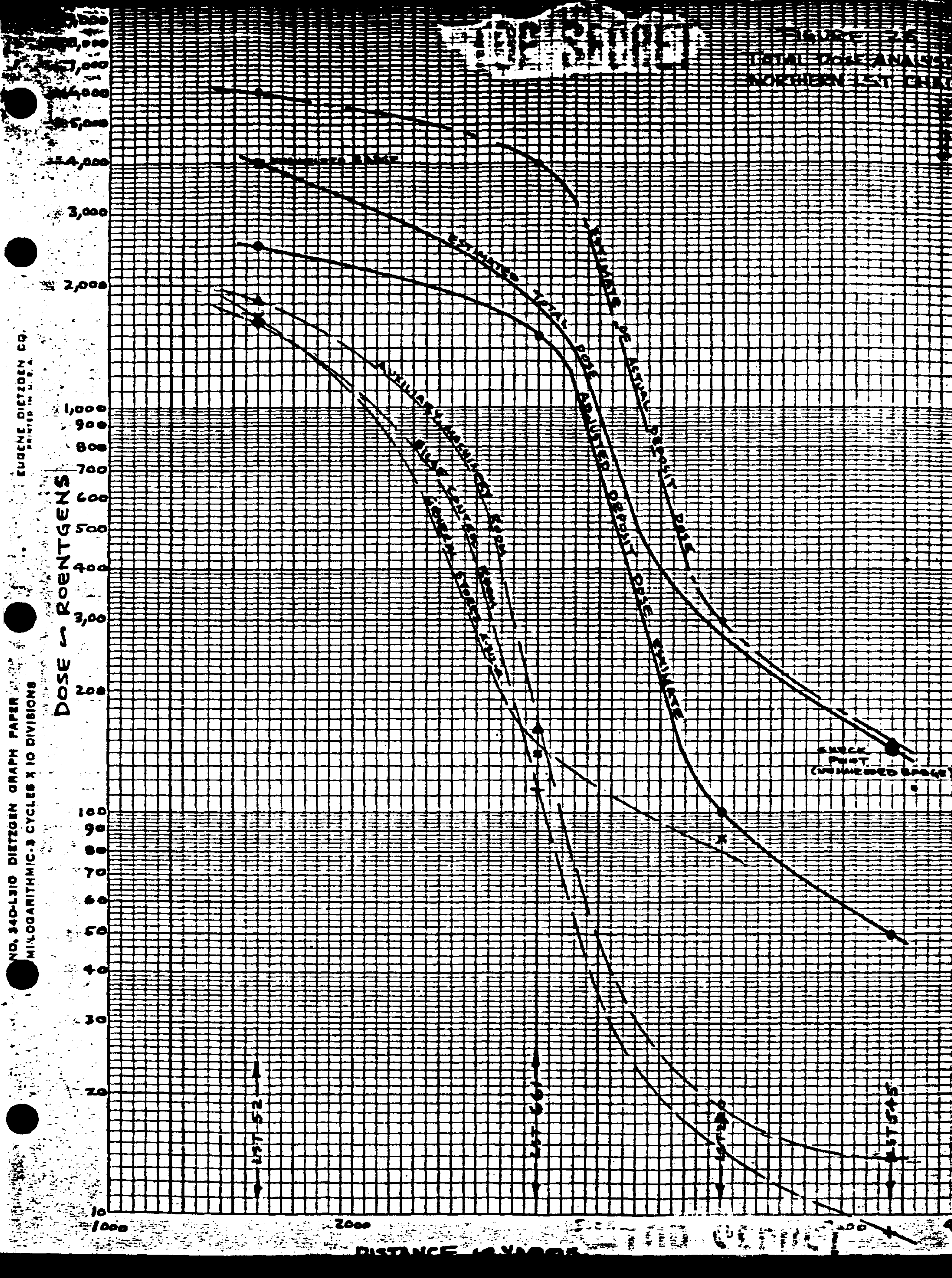
TOP SECRET
FIGURE 26
TOTAL DOSE ANALYSIS
NORTHERN LST CRAFT
DOSE — ROENTGENS
ESTIMATED TOTAL DOSE
ESTIMATE OF ACTUAL DEPOSIT DOSE
ADJUSTED DEPOSIT DOSE ESTIMATE
AUXILIARY MACHINERY ROOM
BILGE CENTER ROOM
GENERAL STORES CPO'S
CHECK POINT (MINIMIZED BADGE)
LST 52
LST 661
LST 825
LST 545
1,000
2,000
3,000
4,000
1000
2000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
DISTANCE — YARDS
NO. 340-L310 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC, 3 CYCLES X 10 DIVISIONS
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FIGURE 27
ESTIMATED TOTAL DOSE

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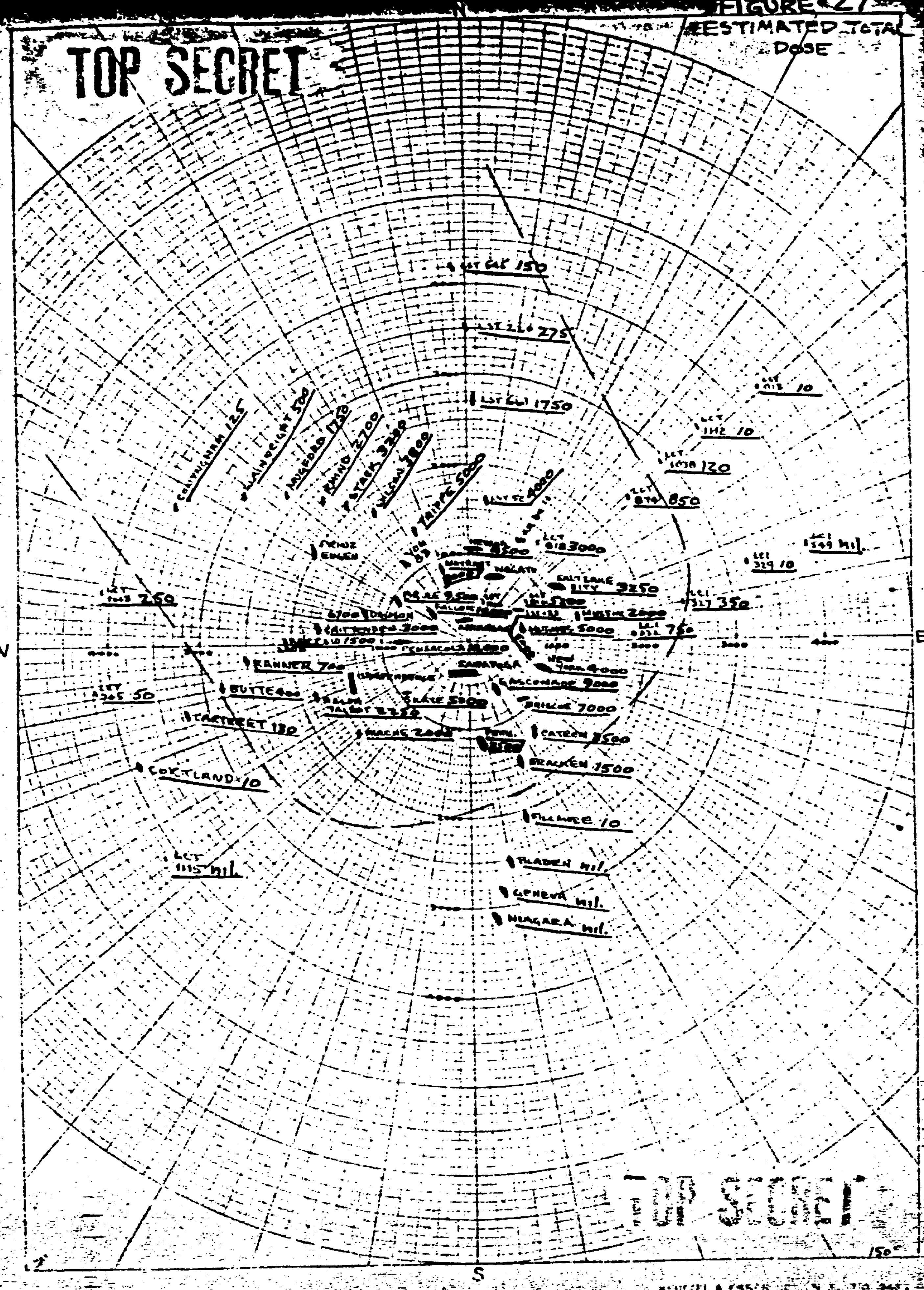

TOP SECRET

KEUFFEL & ESSER

TOP SECRET

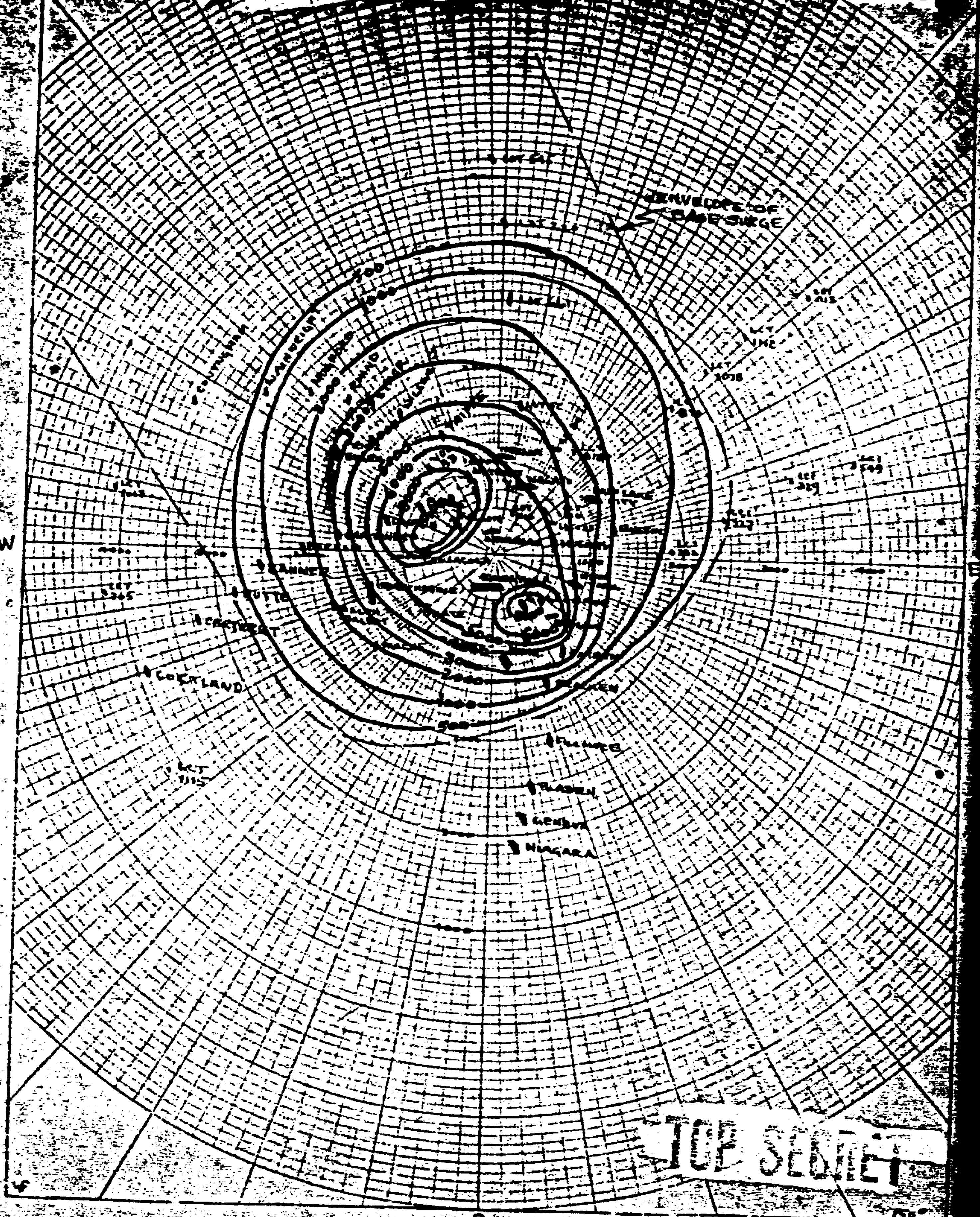

FIGURE 23
CONTOURS OF TOTAL DOSE

TOP SECRET

TOP SECRET

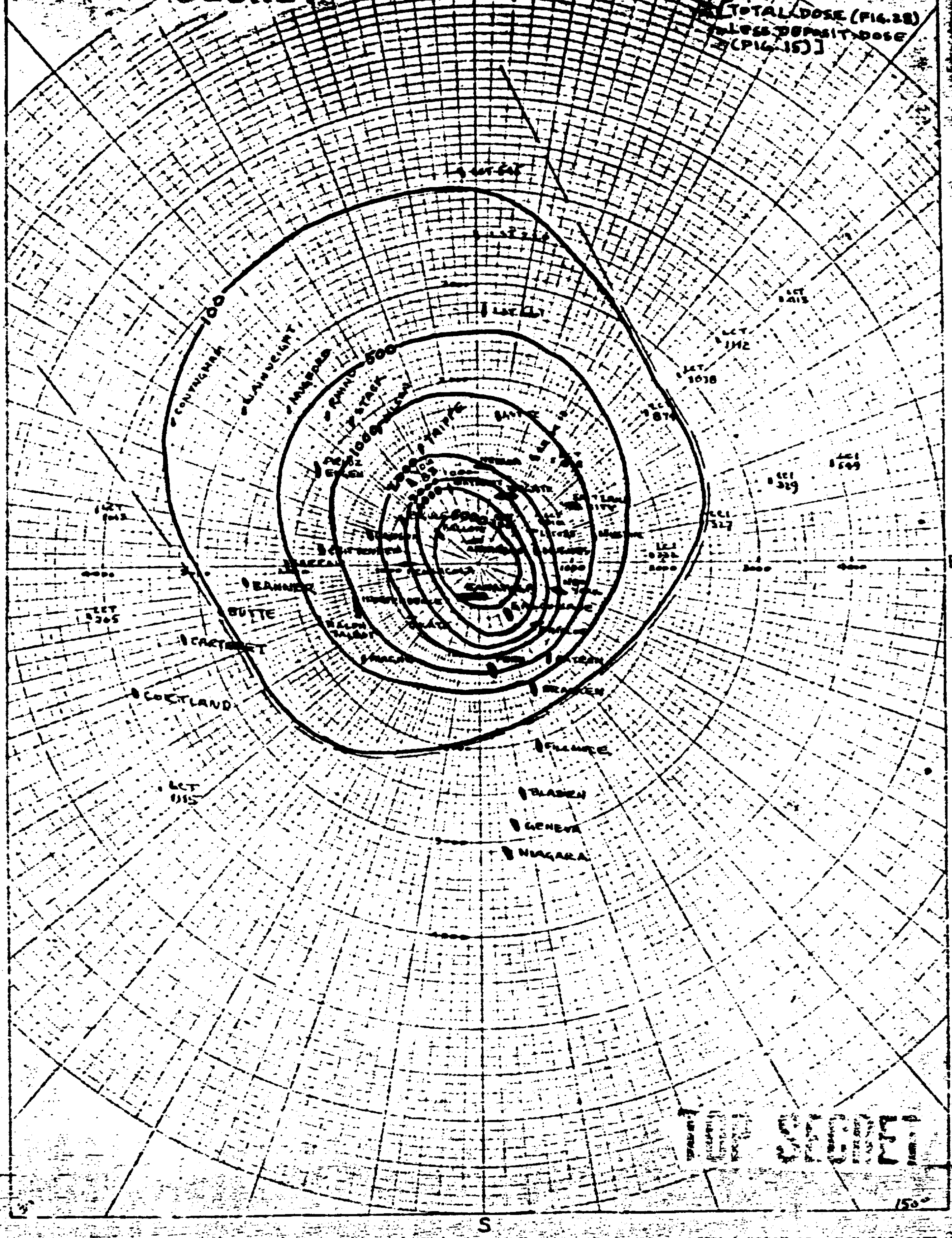

FIGURE 29
CONTOURS OF SURGE RADIATION
[TOTAL DOSE (FIG. 28) LESS DEPOSIT DOSE (FIG. 15)]

TOP SECRET

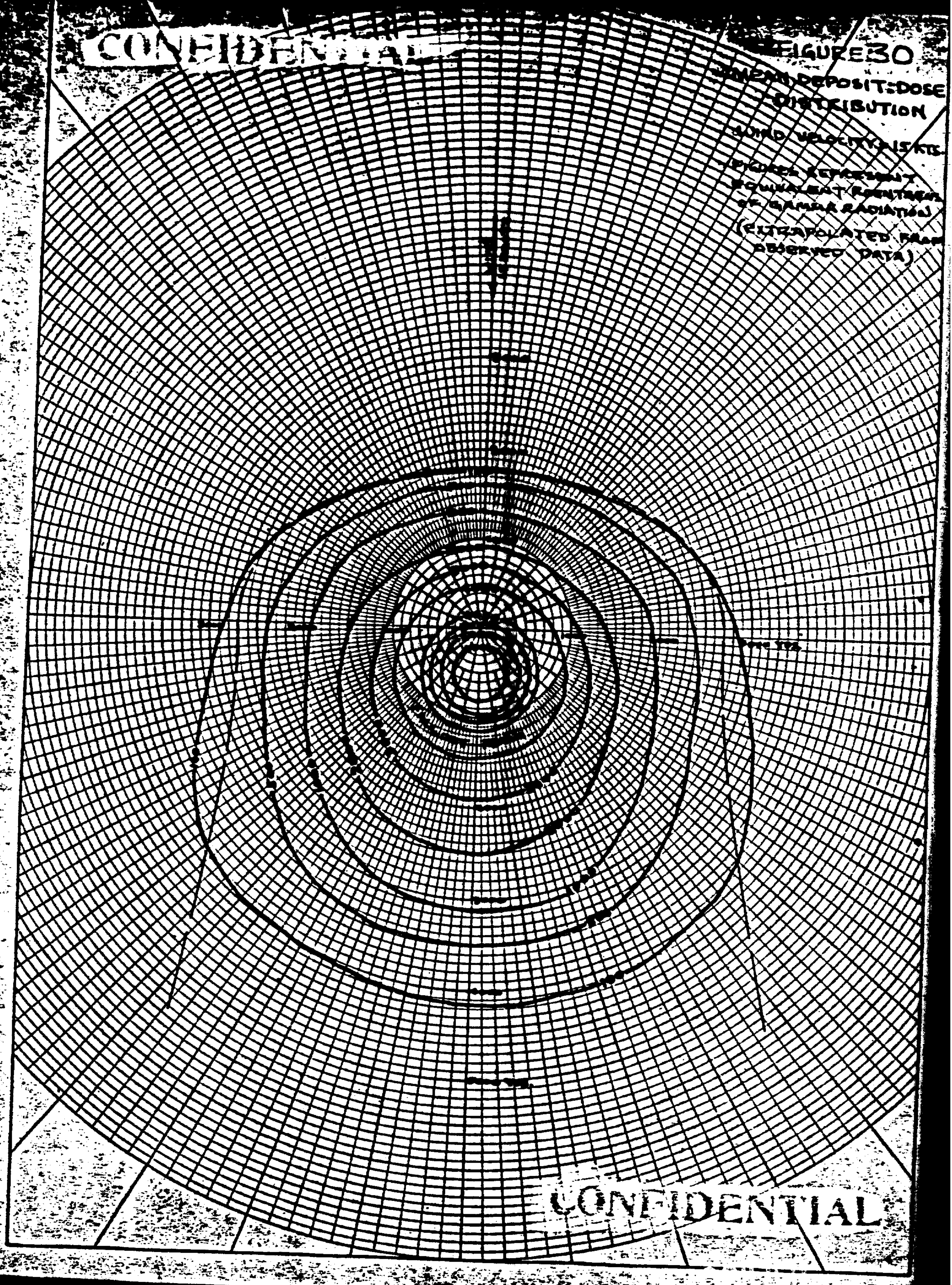
FIGURE 30
DEPOSIT: DOSE DISTRIBUTION
WIND VELOCITY = 15 KTS.
FIGURES REPRESENT EQUIVALENT ROENTGENS OF GAMMA RADIATION
(EXTRAPOLATED FROM OBSERVED DATA)
KEUFFEL & ESSER CO., N.Y. NO.

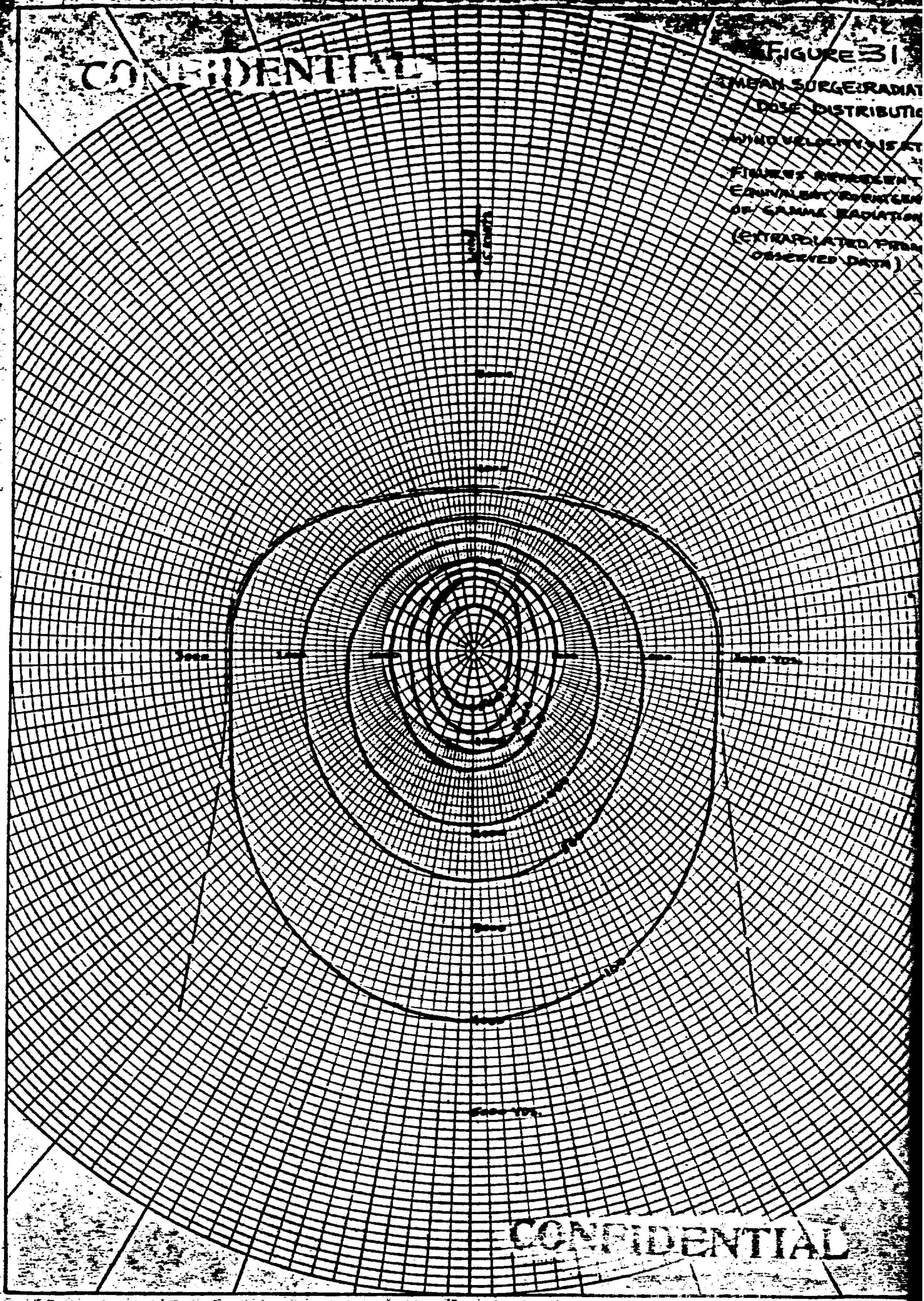
CONFIDENTIAL
FIGURE 31
DOSE
OF GAMMA
OBSERVED DATA)
CONFIDENTIAL

FIGURE 32

MEAN TOTAL DOS[E]
DISTRIBUTION

FIGURES REPRESENT
EQUIVALENT ROENTGE[NS]
OF GAMMA RADIATIO[N]
(EXTRAPOLATED FROM
OBSERVED DATA)